# NEW ENGLAND WATER WORKS ASSOCIATION.

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## SURFACE WATER SUPPLIES OF MASSACHUSETTS.

BY JOHN C. HASKELL, SUPT., LYNN, MASS.

[*Read Sept. 16, 1898.*]

*Mr. President and Members of the Association:*

Although doubtless all present are thoroughly conversant with the character of the water contained in the ponds and streams of your own water systems, you do not all fully realize the character of the water in its entirety throughout the State of Massachusetts. The result desired to be attained in constructing a water system for a city or town, is to secure an abundance of good, potable water at all times fit for domestic purposes, that is, not dangerous to health, or offensive to taste, possessing no odors, and with so little color as not to be readily perceptible when you fill a goblet to quench your thirst.

These requisite qualities seem ones to be easily secured, and it is often claimed by those in charge of our public water supplies, that in fact, in their particular case, they are secured, being the best without exception in the entire country, or one of the best. Any reflection on the character of the water is promptly shown to be a mistake, or is explained by the person consulted, as possibly a local trouble that may be easily remedied at once, or that it will improve from natural causes in a short period of time.

If asked to answer the question, are the surface water supplies of the State, as a whole or individually, capable of furnishing at all times a satisfactory water for domestic use, I should reply without

any doubt that collectively they are not the ideal water to be desired or that might be secured. I will endeavor to present to you some of the reasons on which I base the answer.

We will first consider the dangerous quality as represented by the typhoid germ, the colan bacillus, the most dangerous of all organisms to be feared, but which unfortunately is so minute as to render it impossible of discovery by any examination to which the water is submitted. It neither affects the odor or taste of the water; the fact of its presence in any large numbers is first suspected by the unusual prevalence of the typhoid fever in a community and after an investigation by an expert, the source of infection is found to have been in the water supply. It is generally understood that the typhoid germ can only be present in the water from having been contributed by an actual case of typhoid fever existing within the watershed and which through either ignorance or carelessness is allowed to contaminate the water. In the past, so many epidemics of typhoid fever have been traced to this source that you are all well aware that this source of danger is ever liable to make its presence known in any water supply that is contaminated with sewage. That even an inmate of a family residing in the vicinity of a small stream miles away from the pond or storage reservoir, can thoroughly infect the water of the largest pond; that the presence of a picnic party on the banks of one of the streams is a possible cause of infection. We also have reason to believe that its deadly work is apparent even when not sufficiently frequent to be entitled an epidemic, but can only be suspected from a death rate from typhoid fever in excess of previous years or greater than is to be found in other cities similarly situated.

We will now consider the disagreeable qualities present in the water. To absolutely show to you the character of the water contained in our different supplies, it would be necessary to classify the effect produced upon the water from the presence of each of the 96 different organisms present during the year of 1896 as found by the microscopical examinations of the waters of the State, conducted monthly by the State Board of Health. I will not attempt to make the classification for lack of time, but will assume that the presence of 400 organisms per cubic centimeter will cause the character of the water to be unsatisfactory for domestic use. We find upon an examination of the number of organisms found to be

present in the waters of the various ponds, reservoirs, streams and taps of the surface water supplies of the State during the year of 1896 (when less than twelve examinations were made the result is expressed in twelfths) that applying the standard of 400 organisms per cubic centimetre the water was found to be unsatisfactory in one sample of water in every examination; in one, in 11 of the 12; in two, 10 of the 12; in one 9 of the 12; in three, 8 of the 12; in one, 7 of the 12; in two, 6 of the 12; in three, 5 of the 12; in twelve, 4 of the 12; in seven, 3 of the 12; in eleven, 2 of the 12; in nine, 1 of the 12; in twelve, less than 400. In all of the examinations we find that the water as determined by the analysis and standard taken, would be considered as unsatisfactory for one quarter of the year. To still further show the character of the water and that water containing 400 organisms per cubic centimeter would properly be classified as unsatisfactory, I will present the expressed opinion of the expert who conducted the monthly microscopical examinations for the State Board of Health at the time of making the examinations of the waters of one of the ponds mentioned previously, the waters in which had a general average for the year of 173 organisms per cubic centimeter.

Odor, January cold, none, hot, faintly vegetable; February, cold, none, hot, faintly vegetable; March, cold, faintly vegetable, hot, faintly vegetable; April, cold, faintly vegetable; hot, faintly vegetable; May, cold, distinctly grassy, hot, decidedly mouldy and grassy; June, cold, faintly vegetable, hot, distinctly vegetable; July, cold, faintly vegetable, hot distinctly vegetable; August, cold, distinctly vegetable, hot, distinctly vegetable; September, cold, faintly vegetable, hot, faintly vegetable; October, cold, faintly vegetable, hot, distinctly sweetish; November, cold, none, hot, very faintly vegetable; December, cold, none, hot, none. Of another pond which contained less than 400 organisms per cubic centimeter, at each examination his expressed opinion of the quality is still more forcible. January, cold, distinctly vegetable, hot, distinctly vegetable and mouldy; February, cold, distinctly vegetable, hot, distinctly vegetable and mouldy; March, cold, distinctly vegetable, and mouldy, hot, distinctly vegetable and mouldy; April, cold, vegetable and mouldy, hot, distinctly vegetable and mouldy; May, cold, distinctly vegetable and mouldy, hot, distinctly vegetable and mouldy; June, cold, distinctly vegetable, hot, distinctly

vegetable, and mouldy; July, cold, distinctly vegetable, hot distinctly vegetable and mouldy; August, cold, distinctly vegetable and unpleasant, hot, decidedly mouldy and barnyard; September, cold, distinctly mouldy, hot, decidedly mouldy and barnyard; October, cold, decidedly mouldy, hot, decidedly mouldy; November, cold, distinctly vegetable and mouldy; December, cold, distinctly vegetable, hot decidedly vegetable and astringent.

Of another pond in which the water contained an excess of 400 organisms in ten of the twelve examinations, his expressed opinion is as follows: January, cold, distinctly pleasant, hot, distinctly pleasant and sweet; February, cold, distinctly vegetable, hot, distinctly vegetable and sweetish; March, cold, faintly vegetable, hot, distinctly vegetable and sweetish; April, cold, faintly vegetable, hot distinctly vegetable; May, cold, distinctly grassy and unpleasant, hot, distinctly grassy; June, cold, distinctly grassy and disagreeable, hot, distinctly vegetable; July, cold, decidedly grassy and mouldy, hot, very decided sweet corn odor,; August, cold, decidedly vegetable and grassy, hot, decidedly vegetable, sweet and grassy; September, cold, distinctly grassy and sweetish, hot, decidedly sweet and grassy; October, cold, distinctly vegetable and grassy, hot, decidedly sweet; November, faintly pleasant, hot, distinctly pleasant; December, cold, faintly vegetable, hot distinctly sweetish.

We find upon comparison of the surface waters of the State when judged by the standard of 400 organisms per cubic centimeter that the unsatisfactory water is present one-quarter of the time. When judged by the odor test as applied to two of the ponds previously classed as containing good water, the unsatisfactory odor was present in forty-three of the forty-eight examinations and in the pond in which the organisms exceeded 400 per cubic centimeter, in ten of the twelve examinations the odor test was unsatisfactory in the twenty-four entire tests. Should further proof be required that the surface water supplies of the State, supply water unsatisfactory to many of the takers it may be found in the thriving business done in most of our cities by parties furnishing spring water to the water takers and also in the great number of filters in use on the taps.

The work of our State Board of Health from year to year has demonstrated without question that in the ponds and streams of our various surface water supplies there lurks an insidious danger which

is not possible to be discovered until the unusual death rate from typhoid fever makes its presence plainly apparent, also that no pond or storage reservoir now in use as a public water supply can at all times furnish water of good character such as is proper to be used for domestic use. We find, however, that fully appreciating the dangers inherent in surface water supplies the most careful study has been made by the State Board of Health of the best methods by which the dangerous and disagreeable qualities of the water can be eliminated. No better proof is required that it is possible to render the waters of our surface water supplies the ideal water of the future than can be furnished from a careful study of the results obtained at their experiment station in Lawrence through the most thorough and exhaustive treatment of the subject of sand filtration of surface waters. Also from the object lesson presented in the practical working of a system of sand filtration in the city of Lawrence, designed by Hiram E. Mills, a member of the State Board of Health, which has been the principal factor instrumental in reducing the death rate from typhoid fever in that city from an average per year of 11.26 per 10,000 living for a period of five years (1886 to 1890, inclusive) to one of 1.86 per 10,000 living for the year of 1896. Had the death rate for 1896 continued as large as in the former average, the deaths from typhoid fever from this cause in Lawrence would have been sixty-three instead of the ten deaths that did actually occur. The pages of the reports of the State Board of Health are replete with examples that might be presented to you, all tending in the same direction. The dangers are fully set forth; additional methods for protection are fully explained, an abundance of material is present that might be used to more fully show the character of the water and the best methods to be used for its purification. Sufficient, however, has been said to draw your attention to a subject, the importance of which is such that its discussion will never cease until it is fully recognized that a proper system of filtration is as necessary an adjunct to a surface water supply as is the storage reservoir constructed to impound the storm waters in our streams and retard their flow to their natural home in the ocean until they can be used to supply our needs during the annually recurring periods of a minimum rainfall.

In conclusion, I wish to express as my opinion, that the surface water supplies of Massachusetts are not inferior in quality to those

of the other States of our Union; and also that a surface water supply if properly purified by filtration will furnish water of better character for domestic use than can be secured from an underground system of supply.

DISCUSSION.

MR. CLARK. I think we have all enjoyed this paper of Mr. Haskell's very much; I know I have, and I think it is a good sensible paper. There is much to be said in favor of a surface supply in comparison with a well supply. It is generally a softer water, and one which causes less trouble in many domestic and manufacturing uses. I think the Imperial Board of Health of Germany has probably set us a good example in not allowing the use of any surface water supply until it has been filtered, although we have of course many practically unpolluted surface supplies. Certainly by filtration we can get rid of most of the objectionable features which many of our supplies have. We can remove the organisms, those which we know to be harmful as well as those about which we are doubtful. We can also remove a large proportion of the color, and although we may not have a water even then, in a great many cases, as colorless as that from driven wells, still we will have a good water and a soft water.

MR. RICHARDS. It seems to me that with the outside public, at least, there is a misunderstanding of what we mean when we characterize a water supply, as we sometimes do, as "disagreeable," or as "dangerous," or as "not good water." There ought to be some term employed which would define more closely just what we do mean. Most surface waters that have odors and tastes are not dangerous, though they may be called disagreeable. If a water is polluted with sewage, then it might be called dangerous. Now it does not seem to me it is fair to say that a surface water supply taken from a sparsely settled district, where the watershed is sparsely settled, and where there is reasonable care taken in policing the watershed, should be filtered. I think, taking the cost into consideration, as you always have to, that that water might be said to be a reasonably safe water, and I believe that the assertion that all natural waters whether polluted or not should be filtered, is unwarranted.

# DESCRIPTION OF THE SEPARATE HIGH PRESSURE FIRE SERVICE SYSTEM OF PROVIDENCE, R. I.

BY EDMUND B. WESTON, C. E., CONSULTING ENGINEER.

[*Read Sept. 16, 1898.*]

The water supply of the city of Providence is taken from the Pawtuxet River, in the town of Cranston, and pumped into a reservoir located upon a hill about one mile distant. From this reservoir, the elevation of the water line of which is 180.5 feet, the water flows into the city by gravitation, directly supplying a second reservoir within the city limits, the elevation of the water line of which is 162.5 feet, and also that portion of the city which is below an average elevation of 90 feet. To supply that part of the city above an average elevation of 90 feet, a high service reservoir, the elevation of the water line of which is 274.75 feet, is located in the town of North Providence. The water is pumped by supplementary pumping machinery from the second reservoir above mentioned, or from the low service mains, into the high service reservoir. This supplementary pumping machinery can also supply the high service district if the high service reservoir should be out of service, by pumping directly into the pipes. In addition to the regular pipe and hydrants of the low service in the centre of the business section of the city which is below an elevation of 90 feet, there is a separate high pressure fire service system for protecting an area of about one-half of one square mile, which derives its supply and pressure from the high service reservoir and pumps.

Before the high pressure fire service was installed, the district in which it is located already possessed what would be considered in the majority of cities an ample protection against fire, namely: an abundant water supply, large supply mains and distribution pipes, and 153 hydrants averaging from 200 to 400 feet apart in the streets

where they are located. The static pressure at these low service hydrants averaging from 75 to 40 pounds per square inch, according to the elevation.

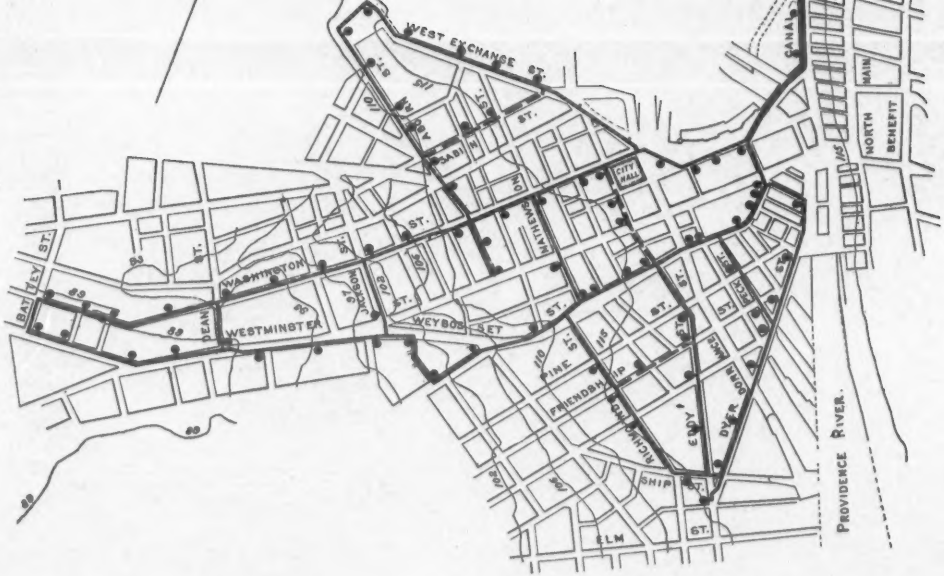
The high pressure fire service system which was completed last October, was built by the direction of the City Council in accordance with the recommendations of the Board of Fire Commissioners. The plans of the work were prepared to conform to the general ideas of the Fire Commissioners in regard to the streets in which the pipe was laid, the location of the hydrants and the quantity of water to be delivered at different points under a specified pressure. The plans also took into consideration a possible addition to the system in the future if it should be deemed necessary, of an auxiliary stationary pumping plant to be located within or immediately adjacent to the district, which would be used solely for fire purposes, and with which the pressure could be increased 50 pounds more than could be obtained from the high service reservoir and pumps.

The high pressure fire service is not to be used for any purpose but fire protection, and its only connections are those leading to the street hydrants of the system. The average static pressure in the pipes is about 44 pounds more than it is in the pipes of the low service at the same elevation. The area of the district which should be able to derive a benefit from the high pressure fire service is about $\frac{56}{100}$ of one square mile. The elevation of about three-fourths of the area of the district, which includes the most compactly built up business portion of the city, ranges trom 10 to 20 feet. The elevation of the remainder ranges from 20 to 79 feet.

The supply of water is taken from the 24-inch high service main leading from the high service supplementary pumping machinery, previously mentioned, to the high service reservoir. This main acts both as a supply and delivery main to and from the high service reservoir, and the high pressure fire service pipe is connected to it at a point a little more than three miles from the reservoir. If the high service reservoir should be out of service, the high service supplementary pumping machinery will supply the high pressure fire service in addition to the regular high service distribution, by pumping directly into the pipes. A check valve is set upon the high pressure fire service pipe near its junction with the high service reservoir main in order to shut it off from the regular high service

# *Providence R.I.*

## *Plan showing the Pipe and Hydrants of the New High Pressure Fire Service.*




*The Irregular lines show, in pounds per square inch (at the surface of the ground along which they run), the Approximate Static Pressure of Fruit Hill Reservoir.*

Plan showing the Type and Highlands
of the Present Water Service.

if the fire pressure should be increased 50 pounds by the aid of the auxiliary pumping plant which has been referred to as a possible addition to the high pressure fire service system in the future.

The total length of the pipe of the high pressure fire service is 29,409 feet; namely: 4,189 feet of 24-inch pipe, 23,004 feet of 16-inch pipe, and 2,216 feet of 12-inch pipe. There are 89 hydrants connected to this pipe.

The average depth of the centre line of the pipe is about 6.25 feet from the surface of the ground, which is about 1.6 feet deeper than that of the ordinary water pipe. The pipe was laid at this depth in order to pass under the ordinary water pipe and other obstructions that were already in the ground, as well as a precaution against the freezing of the water in the pipe of the fire service, which would be more likely to occur on account of its comparative stagnation. As an additional safeguard against freezing, and more especially as about 300 feet of the 24-inch pipe is exposed to the weather on account of passing under two bridges, and owing to the raising of the grade of a few feet of pipe in two or three instances in order to pass over large sewers, a by-pass has been located between the high pressure fire service system and the low service for producing a circulation in severe cold weather, and three blow-offs are attached to the system at convenient points for the same purpose.

For more than four months during the winter of 1897 and 1898 the gate of the by-pass connecting with the low service has been open about two turns, allowing a discharge of about 40,000 gallons per 24 hours into the low service, and every morning during the same period, two of the blow-offs have been opened for about fifteen minutes, allowing a discharge of about 1,100 gallons in addition to that passing through the by-pass. The circulation in the fire service produced by these discharges has prevented the minimum temperature of the water from falling below 37°.

The static pressure at the hydrants of the high pressure fire service ranges from 116 to 85 pounds per square inch, according to the location of the hydrants. At 71 of the 89 hydrants it is more than 100 pounds. The pipe is of such a large size that under ordinary conditions the pressure will not fall below 100 pounds in the centre of the fire service district when an average rate of 5,000,000 gallons per 24 hours, or 3,472 gallons per minute is being drawn from the pipe.

At a test soon after the system was completed, at a hydrant having an elevation of about 10 feet, a good bodied stream of water, flowing at the rate of about 950 gallons per minute, was discharged from a 2½-inch "ring nozzle" to a vertical height of about 137 feet above the ground. The nozzle was supplied through a 12-foot length of 3½-inch hose leading from a jumbo connection, which was fed from the hydrant by two lines of 3½-inch and one line of 2½-inch hose, each 50 feet long.

The plan (Plate No. I), shows the high pressure fire service pipe as it is laid in the district which it is intended to protect, and the hydrants connected to the same. The contour lines show in pounds per square inch (at the surface of the ground along which they run), the approximate static pressure due to the high service reservoir. The pipe and hydrants of the low service, which are laid in all of the streets, are not shown upon the plan.

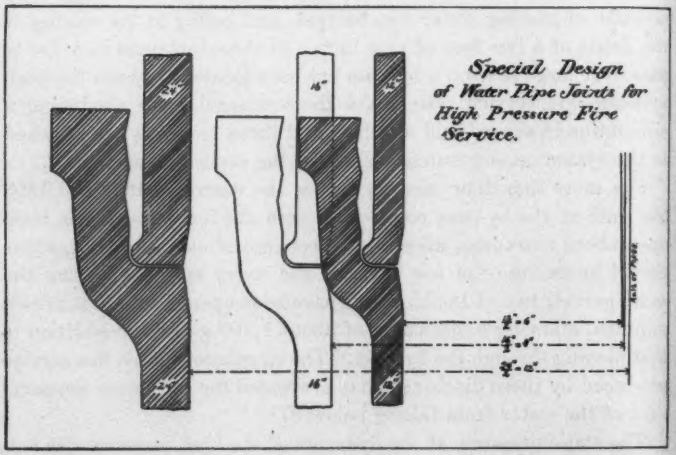



PLATE No. II.

Plate No. II shows a section of the pipe joints, which have a double groove for increasing the resistance of the three inches in depth of lead, which was used for making the joints. These joints were especially designed for the high pressure fire service pipe.

Plate No. III shows the method followed in securing the curved pipe of the system. As will be seen by the plate; collars, lugs and screw bolts were used. This method of securing the curved pipe, which was also especially designed for the high pressure fire ser-

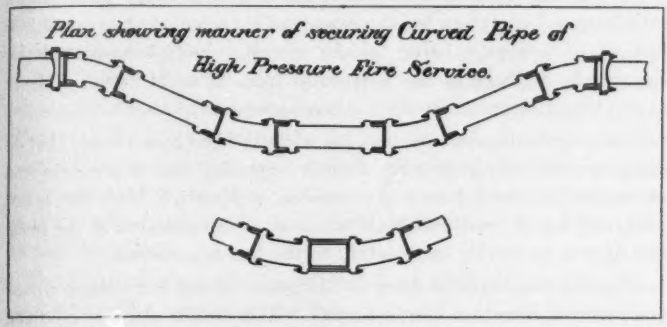



PLATE No. III.

vice, has given great satisfaction, both on account of the quickness with which the work could be done and the security of the same after it was completed.

The high pressure fire service seems to give general satisfaction to all concerned. The insurance rates have been reduced five per cent within the district which it is intended to protect, and an authority in regard to insurance has estimated that the holders of policies within the district will save in ten years, owing to smaller premiums being paid, an amount which will exceed the total cost of the entire system. During a large fire last December, in the opinion of the fire commissioners and others, the system practically "paid for itself," as the fire was kept within the walls of the building in which it originated, by the aid of the high pressure fire service, otherwise it might have spread over a large area and caused a great additional loss of property.

The amount appropriated for building the high pressure fire service was $150,000. The expenditure was $143,175. The estimated value of the pipe and fixtures on hand, to be used for further extension is $3,425, and the cost of the system as completed is $139,750, or $4.75 per lineal foot of pipe laid.

The expense of laying the pipe was considerable; namely: on

account of its being laid in paved or macadamized streets; on account of its unusual depth, which necessitated generally the sheeting of the trench in which the pipe was laid; on account of bad quicksand, which was sometimes encountered, that required the dumping of coarse gravel into the bottom of the trench in order to secure a satisfactory foundation for the pipe, and on account of about 4,300 feet of 16-inch pipe being laid in winter, which necessitated the thawing by artificial means a depth of from 12 to 24 inches of frost at the top of the pipe trench. (See appendix).

It should be remembered, as has already been mentioned, that in designing and doing the work a much larger increase of pressure was anticipated in the future. An increase of pressure, however, is not probable, for at least sometime to come, as the pressure at the present time is eminently satisfactory to the fire department.

The plans and special designs mentioned above were made under the personal direction of the author. The author also directed the construction work. The loss of head due to the friction of the water flowing in the pipe, which was based upon what it may be after the pipe has been ten years in service, was computed by a new formula (dependent upon the age of the pipe), which was constructed by the author.

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## APPENDIX.

### A DESCRIPTION OF THE METHOD THAT WAS FOLLOWED IN THAWING THE MACADAM SURFACING, STONE BLOCK PAVEMENT AND EARTH, WHICH COMPOSED THE UPPER PORTION OF THE TRENCHES OF THE HIGH PRESSURE FIRE SERVICE PIPE THAT WAS LAID IN WINTER.

The thawing was done by steam, with the aid of two bottomless boxes without ends, placed side by side. Each box was 72 feet long, built in six sections of 12 feet, having a top width of 20 inches, a bottom width of 24 inches, and a height of 12 inches. The sections were constructed by nailing spruce boards to skeleton frames, one of which was located at each end of a section. The capacity of the combined boxes was 518 cubic feet. The ends of the boxes were closed by being covered with bagging and earth,

and the joints between the sections were covered in a similar manner. Earth was shoveled around the lower sides of the open bottoms of the boxes where they came in contact with the ground, to prevent the escape of steam. A small portable boiler in which the steam was kept at about 50 pounds, was used for generating the steam. One line of ¾-inch steam hose was run from the boiler through the bagging, into one end of each box for a distance of about 2 feet. A small open space was left in the bagging at the other end of each box, to produce a circulation of steam. At the close of a day's work the boiler fire was banked, the hose removed from the boxes and their ends entirely closed, in order to retain the steam and heat which they contained, as long as possible, and thereby derive all of the benefit that could be obtained from the same during the night.

The total expense of constructing both of the boxes did not exceed $20. The frost averaged from 12 to 24 inches in depth. The top length of trench, 4 feet wide, that was thawed, was 4,300 lineal feet, or an average of about 71 lineal feet per day. The average cost of thawing was 6.7 cents per lineal foot, or 1.7 cents per square foot of ground surface area.

DISCUSSION.

MR. FRENCH. The system described in Mr. Weston's paper is certainly of value to all interested in preventing fire waste. There is nothing so good as a gravity system. It is working nights and Sundays and holidays, and there is no delay in starting pumps. In large cities the steamers are gotten into operation very quickly, to be sure, but in smaller towns it takes some little time to get everything going. The department is not called out very often, and consequently there is apt to be a delay, so that the advantage of a high pressure system supplied by gravity is obvious. Apparently somewhere about 100 pounds pressure is enough for ordinary fire service, and perhaps is as much as the firemen can conveniently handle. The higher pressure makes the streams, when short lines of hose are used, rather unmanageable. With 100 pounds as the limit, hydrants must however be placed at such frequent intervals that lines of hose longer than 300 feet will not be necessary, otherwise the hose friction becomes a serious loss.

There is one point which it is to be regretted we cannot ask Mr.

Weston about, and that is just how he figured the pipes for friction loss. Some experiments made last summer in Lowell by the proprietors of the locks and canals furnished some interesting data as to their old pipes. There was a 12-inch pipe coming from their reservoir to the mill system, nearly a mile in length, which was laid in 1849, and was not tar coated or otherwise protected from corrosion. Some tests were made of that pipe in connection with the general testing of the fire system. The water was discharged through some large nozzles, the pressures at the nozzles being measured by a piezometer with an ordinary Bourdon gauge, and the quantity flowing thus determined. The pressures were then taken at a hydrant some distance up stream from the point where the nozzle was connected, using again an ordinary gauge. The loss of pressure was shown by the difference between the ordinary static head and the pressures recorded with different quantities of water flowing. It was found that this 12-inch pipe, fifty years old, had become so corroded that it had no greater capacity than a new, clean 8-inch pipe, which means that the friction loss was roughly about five times what Mr. Weston gives in his published tables for new, clean 12-inch pipe. Some years ago, I am told, when that pipe was being repaired, a short section was taken out and it was so covered with tubercles that a 10-inch plug was the largest which could be drawn through, and that probably knocked off the tops of some of the largest bunches, showing how very serious the incrustation had become. There was another 12-inch pipe nearly parallel to this one, laid about thirty years ago, and that showed a loss, tested in the same way, of about twice what Mr. Weston gives, speaking roughly. That was a tar coated pipe. These pipes were not straight, there were many bends in them. Similar tests at the same time, of 8-inch uncoated pipes laid about fifty years ago, showed a carrying capacity less than a new, clean 6-inch pipe. Such data shows the effect of time in reducing the carrying capacity of a pipe, and indicates that a fire system which is designed to be thoroughly efficient, after twenty-five or thirty years of use must be laid out on a liberal enough scale to allow for this unavoidable corrosion.

## CORRESPONDENCE.

MR. WESTON. Mr. French has referred to the author's tables published in 1896, which show the loss of head due to friction in

pipes, and compares experimental data relating to an originally tar coated 12-inch pipe about 29 years old with losses of head given in the author's tables for new pipes. A comparison of the results obtained during the experiments made with this pipe, as contained in the "Test of the Fire System Belonging to the Proprietors of Locks and Canals made in 1897," with losses of head that have been worked out from an originally tar coated 12-inch pipe 29 years old, by the aid of the tables in the author's book, which are arranged to apply to old pipes that were originally coated with tar as well as for new pipes, show that the losses of head thus deduced do not differ very materially from average experimental results derived from the 12-inch pipe above mentioned:

| Gallons of water flowing in the pipe per minute. | Loss of head in pounds per 1,000 feet in an originally tar coated pipe 12 inches in diameter and 29 years old. | |
|---|---|---|
| | From diagram showing results of experiments above referred to. | Computed by Weston's tables. |
| 500 | 0.76 | 0.55 |
| 1000 | 2.30 | 2.22 |
| 1500 | 4.70 | 4.99 |
| 2000 | 8.00 | 8.87 |

# METHODS FOR THE DETERMINATION OF COLOR AND THE RELATION OF THE COLOR TO THE CHARACTER OF THE WATER.

BY FREDERICK S. HOLLIS, BIOLOGIST, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read Sept. 14, 1898.*]

## THE COLOR OF SURFACE WATER.

In 1880, Tidy[1] stated that "The color of a surface water is caused by the peaty or vegetable impurities, and the color varies with the condition of the vegetable matter present." He stated further that the color imparted by a recently formed peaty material is yellowish green, that by a recent peat a brownish olive green, while that obtained from old peat is a true brown or coffee color entirely free from the olive tint.

Dr. Drown[2] reached the same conclusion by preparing artificially colored water by extracting leaves in distilled water, and showed also that for the same color the amount of albuminoid ammonia was less in subsequent extractions.

| | Color. | Albuminoid Ammonia. |
|---|---|---|
| First infusion of leaves | 0.80 | .0494 |
| Subsequent infusion of same leaves | 0.80 | .0174 |
| Infusion of old leaves | 0.90 | .0072 |

It was further shown that by decolorizing a surface water having a color of .80 or .90 by means of hydrate of alumina, about 85 per cent. of the albuminoid ammonia was removed. Infusions of animal matter, while they have very little color, are very rich in albuminoid ammonia, which, however, is not removed by treating with hydrate of alumina.

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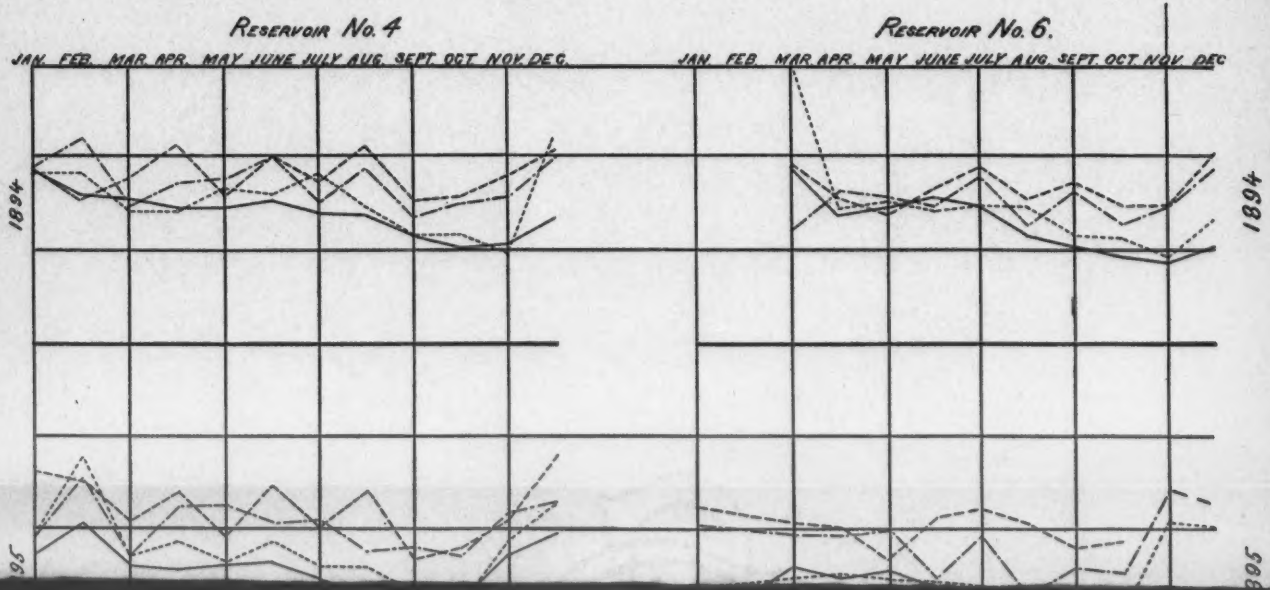
[1] Jour. Chem. Soc. 1880, p 293.
[2] Technology Quarterly, 1888, p. 256.

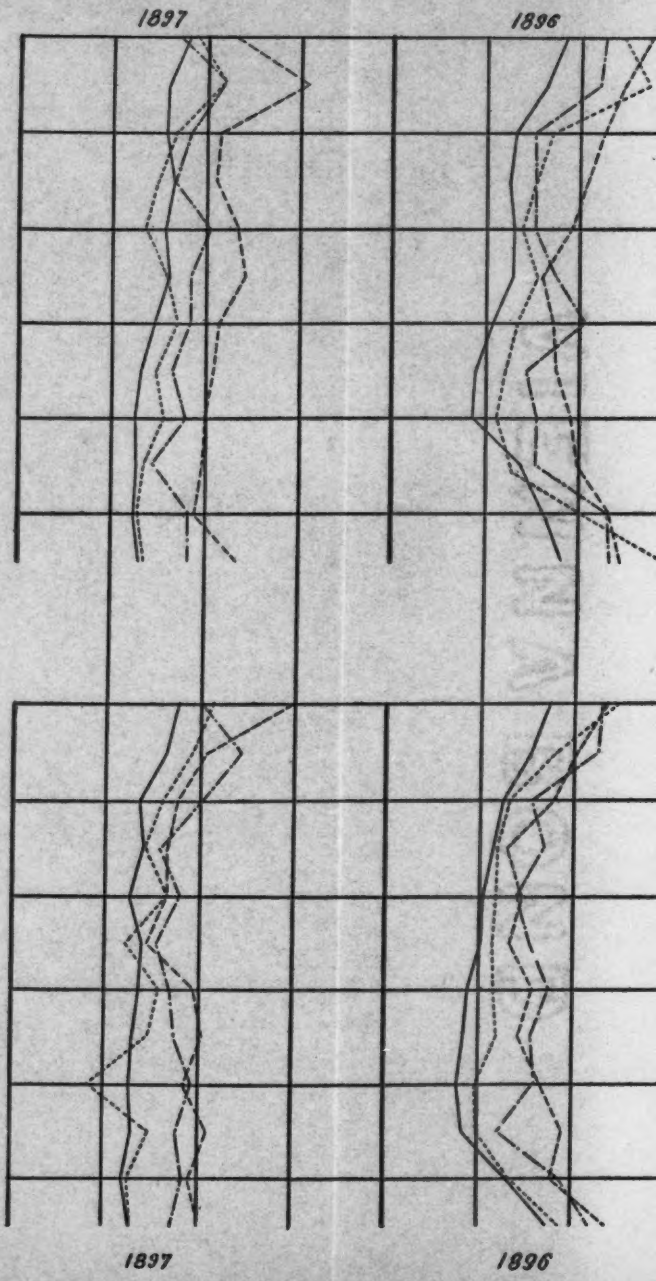
# PLATE A.

BIOLOGICAL LABORATORY, BOSTON WATER WORKS.

COLOR, 20 DIVISIONS = 1.00 ———
OXYGEN CONSUMED, 20 DIVISIONS = 1.00 ----------
LOSS ON IGNITION, 20 DIVISIONS = 2.00 ——·——
ALBUMINOID AMMONIA IN SOLN., 20 DIVISIONS = .0200 — — — —


RESERVOIR No. 4
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1894
RESERVOIR No. 6.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1894

1895
1895


1897
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1896

Analyses presented by Mrs. Richards[1] of the residue from Boston tap water[2] and the dark water from Cedar Swamp in Westborough, Mass., as well as that of humic acid[3] derived from brown vegetable mould show the following results:

| | Color of water. | Carbon. | Hydrogen. | Nitrogen. |
|---|---|---|---|---|
| Residue, Boston tap water | 0.57 | 30.71% | 5.96% | 7.68% |
| Residue, Cedar Swamp water | 4.00 | 43.72 | 3.92 | 4.82 |
| Humic acid | —— | 50.40 | 4.80 | 3.60 |

Solutions which agree well in color with a peaty water can be prepared from caromel or charred sugar which contains no nitrogen.

The foregoing analyses, showing the closer relation between the color and the carbon contents of the residue obtained on evaporation, agree well with the fact that the color of a water follows most closely the determination of the amount of carbonaceous matter in solution, as shown by the test of the oxygen consumed or the power of the water to take oxygen from potassium permanganate.

In the case of a normal or unpolluted surface water which receives a constant supply from an uninhabited area there is generally a close agreement between the color, the oxygen consumed, the loss on ignition and the nitrogen as shown by the albuminoid ammonia in solution. This is due to the fact that it receives the different constituents in about the same relative proportions.

This is shown on Plate A for the Ashland and Hopkinton reservoirs of the Metropolitan Water Works (formerly reservoirs No. 4 and 6 of the Boston Water Works) in which the fluctuations of the various components are seen to follow the color in a general way. The greater regularity of the line representing the color is due to the fact that it is the average of weekly readings while the others are based on single monthly analyses.

In the case of such unpolluted dark waters the color is a ready means of forming a somewhat rough comparative estimate of the condition of the water with regard to the presence of those substances represented by the oxygen consumed, the loss on ignition and the albuminoid ammonia in solution. From this rather close agreement between the color and the other substances present in the case of a

[1]Jour. Am. Chem. Soc., Jan. 1896.
[2]H. T. Gallup. Thesis, Mass. Ins. Tech., 1894.
[3]Berthelot. Compt. Rend., 569, 1892.

water from an uninhabited area we pass by steps according to the extent of pollution to the other extreme in the case of a highly polluted colorless water, especially in the case of pollution by sewage, where there is no connection between the color and the chemical impurities.

Water in contact with soil takes up the extractive matter from the organic constituents of the soil, which appears as chemical impurities and also adds to its color. This is of special interest in connection with the determination of the depth to which a site for a reservoir needs to be stripped.

By a careful study of the soils from the site of the proposed Wachusett reservoir made by the Massachusetts State Board of Health,[1] it was found that 50 grams of surface soil in contact with one liter of water for eighteen hours imparted a color of from .20 to .60 according to the nature of the soil, while in the case of land recently cleared of good sized timber, even a greater amount of color was imparted, and that this soil continued for a long time to impart color to the water.

The amount of color imparted, as well as the material dissolved, as revealed by chemical analysis, decreased rapidly in soils from below a depth of 9 to 11 inches, and it was decided that an amount of organic matter represented by a loss on ignition of from 1.5 to 2 per cent. of the weight of the sample dried at 100° C. was a safe amount to leave in the bed of a reservoir.

The apparent color of a surface water is often influenced by an increase in the turbidity of the water. Such an increase in color caused by turbidity was noted in Framingham reservoir No. 3, and its influent stream during the construction of the Sudbury reservoir on the influent stream above it. Most of the work causing the turbidity was done during the years 1894 and 1895.

| | Color. Reservoir No. 3. Influent | Color. Reservoir No. 3 at dam. |
|---|---|---|
| 1893 | .71 | .71 |
| 1894 | 1.00 | .77 |
| 1895 | 1.05 | .82 |
| 1896 | .75 | .62 |
| 1897 | — | .58 |

It is our custom to report the color of the unfiltered water, as an

[1]Rept. Mass. State Bd. Health, XXV.

increase of color due to turbidity is apparent, generally persists, causing an increase of color in the reservoirs lower in the series, and any increase of color of the lower layers due to stagnation is only safely estimated after transportation to the laboratory by the color of the unfiltered water.

### INCREASE OF THE COLOR OF WATER DUE TO STAGNATION.

Twice a year, generally during April and November, the surface layer of a body of water acquires the temperature of greatest density, 39.2° F., and in consequence sinks to the bottom, thus causing a circulation of the water of all depths. At other times there is no cause for the water of different depths to mix except the action of the wind, which only rarely extends to a depth of thirty feet.

Thus the water at the bottom of a deep pond or reservoir is stagnant during the greater part of the year and, unless the water is of exceptional purity, marked changes take place in the character of the water, one of the most noticeable of which is a material increase of color. The chemical analysis of such a dark water from the bottom of a stagnant pond or reservoir shows an accumulation of organic matter which is undergoing a putrefactive change.

Water if exposed freely to the air absorbs oxygen in amounts varying with the temperature from about 1.00 per cent. of its volume, just above the freezing-point to 0.54 per cent. at 88° F. In the case of water of the surface of a pond, which is at all times exposed to the air, this supply of oxygen which is held dissolved in the water is sufficient to oxidize the products of decomposition as they are formed and when used up it is immediately replaced. In the lower stagnant layers this supply of oxygen is soon exhausted and, as no more can be taken up, the products of decomposition cannot be carried to their final or harmless form until the spring or autumn overturn of the water. Indeed the avidity of the decomposing organic matter for oxygen is such that, when the water is once deoxidized, the nitrates contained in the water are reduced and the oxygen contained in them appropriated. Such a water is characterized by low nitrates and high free ammonia as well as by high albuminoid ammonia and oxygen consumed.

Under these conditions iron is reduced and taken into solution

in considerable quantity, amounting in some cases at the bottom of Lake Cochituate to nearly 2.00 parts per 100,000.

This iron in solution adds materially to the increase of the color of a stagnant water and, upon bringing a sample to the surface, increases the color and unpleasant appearance still further by its oxidation and separation.

A supply in which any considerable proportion of its water at the bottom has undergone these changes due to stagnation during the summer always shows an appreciable increase in color at all depths at the time of the autumn overturn of the water.

An idea of the increase of color due to stagnation is obtained by comparing the color readings of the water at the surface of Lake Cochituate with those from the bottom (60 feet) at the time of maximum stagnation.

| | Color. |
|---|---|
| Lake Cochituate, surface | .22 |
| " " bottom (60 feet) on collection | 1.20 |
| " " " " after exposure to the air | 3.70 |

The temperatures and colors for the surface, mid-depth and bottom of Lake Cochituate during the period of one year showing the effect of stagnation are given on Fig. 1 and Fig. 2. Lake Cochituate was selected for the study of the effects of stagnation on account of its great depth at a single point where no mixing of the water occurs except during the spring and autumn overturn, but it is not to be understood that Lake Cochituate is for that reason an objectionable source. The slight increase in color of the water of the upper layers after the autumn overturn shows clearly that the amount of water affected by the stagnation is very small compared with the total volume of the water of the lake.

It is interesting to note in this connection that of the reservoirs of the Metropolitan system, the one which has shown least tendency to these unpleasant results receives a very dark colored water from an uninhabited area. Temperature readings show that it is, like the other reservoirs, stagnant during the greater part of the year.

The study of many of the dark surface waters of the State has shown that dark water of such character is remarkably stable and unobjectionable from a sanitary standpoint.

## COLOR IN GROUND WATER.

Ground water when derived from a source having a covering of peat, which is not infrequently the case when the site has been selected in a valley so as to realize the greatest yield from the watershed, is often colored through the influence of the peaty layer. This peat may be of comparatively recent origin forming the surface or, if the wells are of great depth, the peaty layer may represent an accumulation of some former period, in which case its influence is generally even more marked. Oxygen is taken from

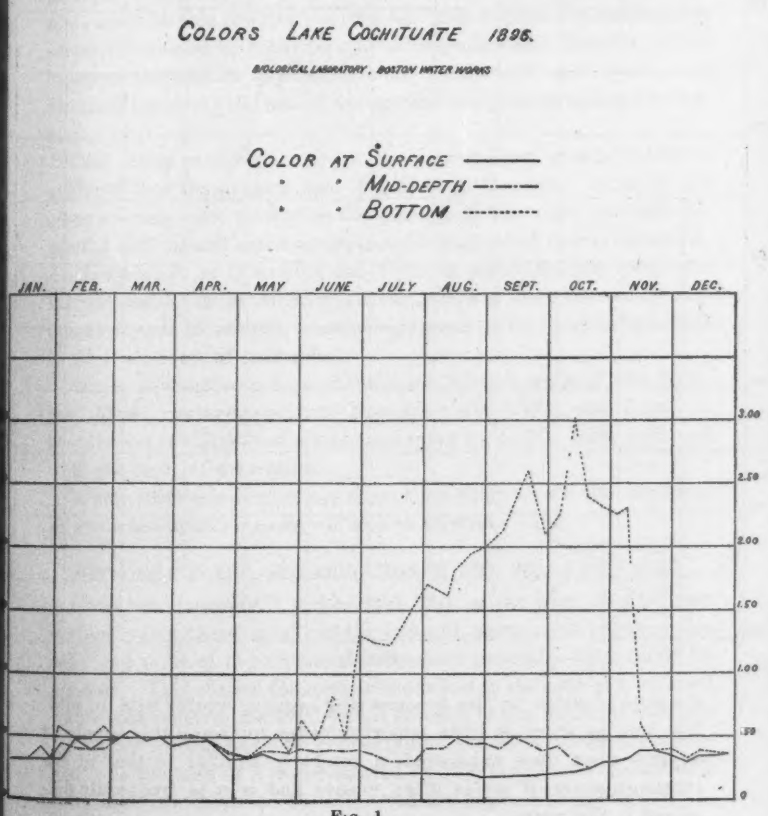



FIG. 1.

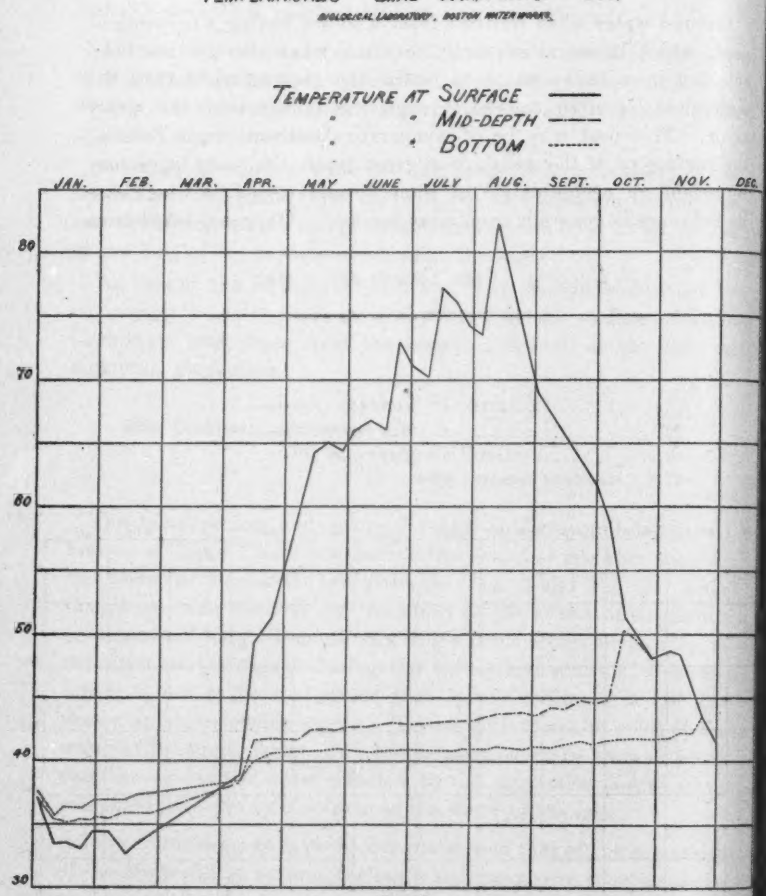



FIG. 2.

the ground water by the decomposing organic matter held in solution and, as there is little opportunity for replacing this supply of oxygen when once exhausted, a condition similiar to that in the stagnant layers of ponds often ensues and iron is frequently dissolved in the water.

On bringing such a water to the surface, the iron which it contains is slowly oxidized but, on account of the power of some organic substances to prevent the complete precipitation of iron, it is removed too slowly by natural means to admit of its use as a source of supply.

Peifke and Fränkel devised a means of removing the iron from certain Germany city supplies derived from ground water, depending upon the rapid oxidation of the iron, by passing it in the form of spray through a column of coke and the subsequent removal of the precipitated iron by means of rapid filtration through sand. In some cases in this country the iron has been sucessfully removed by aeration obtained by spraying and subsequent rapid filtration, while in others the iron is apparently more firmly held and mechanical filtration involving the use of a coagulant has been considered necessary.

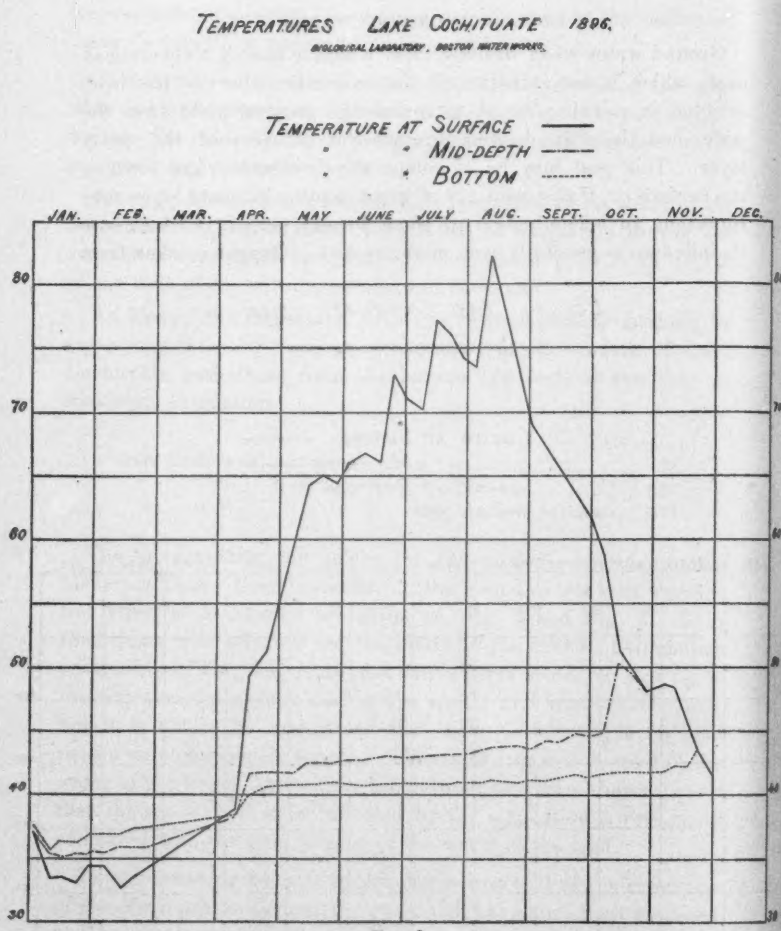
That many excellent supplies are drawn from ground water is evidence that the oxygen held dissolved in the water is not in all cases entirely used up during the passage of the water through the ground and in such cases no appreciable amount of iron is dissolved. Analyses made on December 1st, 1892, of water flowing from two tubular test-wells at Medford, Mass., showed that the water contained oxygen in solution amounting in one to 23.7 and in the other to 24.1 per cent. of saturation.

Water flowing from four of the many tubular wells of the Newton, Mass., water-supply on November 19, 1892, was found to contain oxygen dissolved which amounted to 12.92, 3.48, 0.89 and 3.28 per cent. of saturation.

Water from this source has at no time since shown the presence of any considerable amount of iron in solution.

### METHODS FOR THE DETERMINATION OF THE COLOR OF WATER.

From the foregoing it will be seen that in the case of a normal surface water there is a certain general agreement between the color and some of the chemical substances generally determined by analysis. This chance for comparison is lost in the case of a polluted water that receives material which appears in the chemical analysis as impurities but bears no connection to the color-producing material. In the case of a water colored by iron there is no opportunity for comparison between the color and the organic impurities.

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If, therefore, a method for the determination of the color is desired it is necessary to resort to some other means.

The most ready means is a direct comparison of the color with some standard of color produced in a definite way, and this has been done by a variety of methods. Most of the methods have some special advantage or are particularly well adapted for the determination of the color of the class of water for which they were used.

The method of varying the depth of the column of water to match a definite and fixed color standard, and that of comparing a definite depth of water with varying depths of standard, or a set of standards of the same depth but different intensities, or with a set of colored glass plates have been used.

The medical commission appointed to investigate the sanitary qualities of certain sources with reference to the increase of the Boston water-supply* made their observations on the color of the water by means of an instrument in which the depth of the column of water was varied so as to match the intensity of color of a plate of brownish-yellow glass. While this method served to make a comparison of the color of the water from these different sources, most of which are similar dark colored waters, it is not a method to be recommended for general use as the selection of the glass of particular hue is an arbitrary one which would not be well suited for the comparison of water from souces of a different character. It would also be difficult or impossible to describe such a color standard in a way that it could be duplicated for use in different laboratories. The method did not survive the purpose for which it was proposed.

A method has been recommended consisting of filling half full a two-foot tube of considerable diameter provided with plate glass caps. When this is held horizontally the water occupies the lower half and the lower half of the circular field is illuminated by light which has passed through the water. The comparison is made by placing colored plates or small bottles containing colored liquids in front of the upper half. This is a cumbersome method, the accuracy of which depends upon the selection of suitable color standards and, moreover, few of our waters can be read in tubes of such length.

It may be interesting to note that four-foot glass capped brass

*City Document, Boston. No. 102, p. 104.

tubes, having a diameter of four inches, were found very useful at the Experimental Filter Station of the Boston Water Works for comparing roughly the color and also the turbidity of the light colored effluents from the filter-tanks.

The instrument commonly used for the estimation of the color of water in England is the *Tidy Colorimeter which consists of two two-foot tubes with glass ends, the ends opposite the observer being closed by ground glass. The tubes are mounted one above the other on a stand, the water to be examined placed in one and a corresponding amount of distilled water in the other to compensate for loss of light due to the depth of water. The comparison is made by placing glass wedges filled with different colored liquids in front of the tube containing distilled water, and the position of these wedges is changed, thus interposing more of one color or the other, until the resultant agrees with the color of the sample. The solutions used are bichromate of potash for the yellow and sulphate of copper for the blue, and the color is reported in terms of so much yellow and so much blue as read off on a scale marked on the wedges.

While this method may serve for the estimation of the color of water of English supplies, most of which are light colored, and of effluents from filter-beds it became necessary to make the solutions at least ten times as strong as recommended in order to secure sufficient of the yellow hue to match our surface waters when viewed in tubes of such length and, moreover, the red which is so prominent in most of our surface waters is entirely ignored. On account of the use of wedges, the color varies somewhat on different sides of the circular field and it is also necessary, on account of the use of two tubes, to compare the color of the water as seen with one eye with the color of the standard as seen with the other.

The recommendation of Prof. A. R. Leeds,† that the Nesslerized ammonia standards used in estimating the amount of ammonia be used as standards for the comparison of the color of water is of special importance to us as it was very generally adopted in this country, and all results are reported in terms of this standard or of some scale based directly or indirectly upon it.

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*Crookes, Odling and Tidy. Chem. News 43, 174. Am. Chem Jour. 14, 300.

†Proc. Am. Chem. Soc., 2, 8.

The Nessler scale consists of a set of seventeen standards of a volume of fifty cubic centimeters containing from 0.1 to 5.0 c. c. of dilute ammonia solution, each cubic centimeter of which contain .01 mgr. of N $H_3$. When treated with the Nessler reagent they have a brown color not unlike that of our surface waters, the intensity of which varies with the amount of ammonia solution added to each standard. The standards, as well as the water to be examined, are placed in glass tubes, closed at one end, of a diameter of 15 to 20 milimeters and 300 milimeters in length.

The turbidity of the standard increases with the amount of ammonia solution present, which makes it difficult to match the water against the higher standards, and moreover, the material causing the color of the standards is not permanent and is liable to precipitate by handling the standard tubes on account of its unstable nature. Recent work has also shown that the intervals of the scale are not regular.

### NATURAL WATER STANDARDS.

Standards made by diluting a dark surface water with distilled water to match the different standards of the Nessler scale have been used successfully. Standards made in this way have the same hue as the waters to be matched, as well as a turbidity which corresponds well with that of surface waters, but the irregularities of the scale are the same as the Nessler standards, which they are made to match.

Natural water standards are fairly permanent if protected from the light, but gradually grow lighter and must be compared frequently with a fresh set of Nessler standards.

By means of the Lovibard tintometer[1], a satisfactory set of natural water standards can be standardized in terms of definite plates of colored glass. By comparing a new set of standards with these plates they can be made at any time comparable with the previous set.

The tintometer consists of two tubes, arranged not unlike those of the Tidy colorimeter, in one of which the standard under examination is placed and in the other the graded colored glasses. The color is represented by the aggregate of the tint numbers of the glasses required to match the standard. No attempt is made to

[1]Ellen H. Richards and J. W. Eellens. Jour. Am. Chem. Soc., XVII, 1896.

correct the irregularities of the scale of the natural water standards, which we have already seen are the same as those of the Nessler standards.

PLATINUM STANDARD.

According to the platinum standard, introduced by Mr. Allen Hazen,* "the color of a water is the amount of platinum, in parts per ten thousand, which in acid solution, with so much cobalt as will match the hue, produces an equal color in distilled water." In practice, a standard having a color of 5.00 is prepared by dissolving 1.246 grms. of potassium platinic chloride, (=.5 grm. platinum) 1.000 grm. of cobalt chloride (=.25 grm. cobalt), and 100 c. c. of concentrated hydrochloric acid in distilled water and making up to one liter.

Dilute standards for matching the color of the water are prepared by diluting quantities of this stock solution to 50 c. c. with distilled water. By diluting 1 c. c., 2 c. c., and 3 c. c. to 50 c. c., colors of 0.1, 0.2 and 0.3 are obtained.

The intervals on the platinum standard are similar to those of the Nessler scale. The two standards are practically the same at 0.40, below which the platinum standards are lighter colored, and above which they increase regularly, so that a color of 1.50 on the platinum scale is equal to 2.00 on the Nessler scale.

The platinum standard is permanent if protected from dust, and as it is prepared by weighing accurately quantities of a definite crystalline chemical compound, it can be prepared in any laboratory. The intervals of the scale are regular, the color is directly proportional to the depth, and it is free from the objectionable turbidity noticed in the case of the higher Nessler standards. The color is not influenced by the temperature or method of preparation as is that of the Nessler standard.

In 1892, a form of colorimeter was devised by Mr. W. E. Foss under the direction of Mr. Desmond FitzGerald[1] for use at the Experimental Filter Station of the Boston Water Works, which embodied much that was new in its application to the estimation of the color of water. The following description and plates are reproduced from the description of the colorimeter published in the Report of the Boston Water Supply Department.

*Am. Chem. Jour., XIV., No. 4.

[1]Ann. Rept. of the Water Supply Dept., City of Boston, 1893.

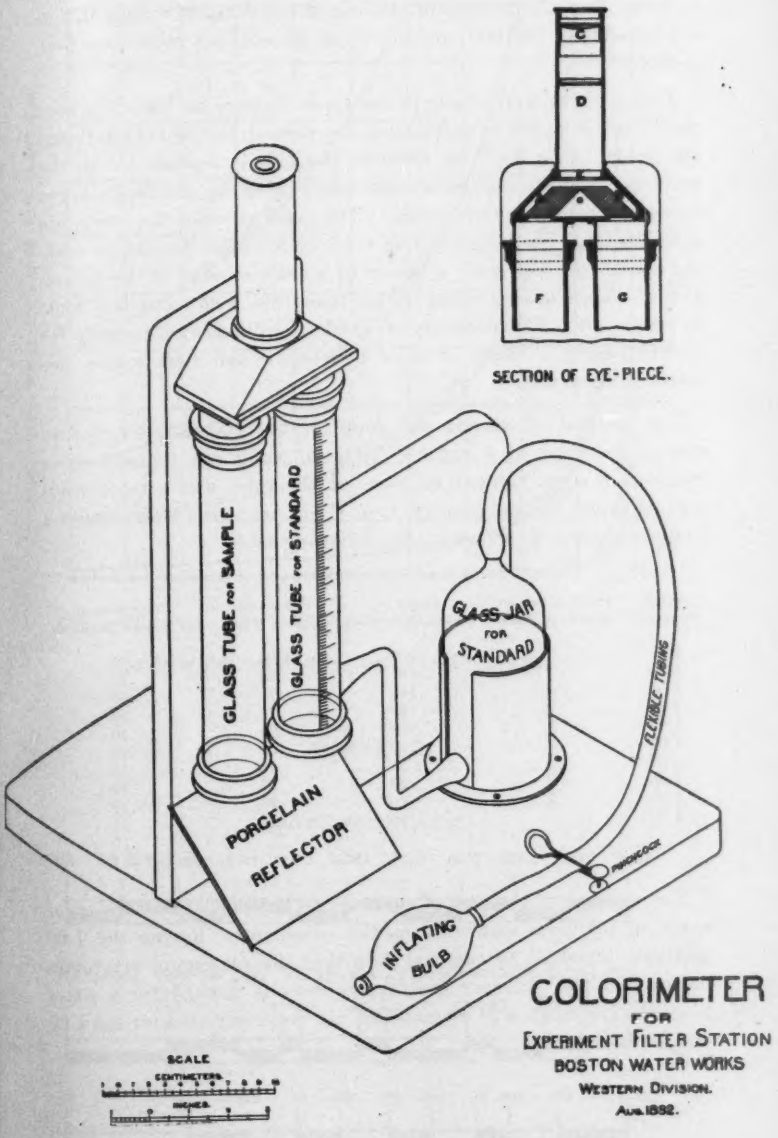
An isometric projection of the complete instrument and a section of the eye-piece are shown on the following plate. "The latter consists of two totally reflecting prisms A and B and a magnifying lens C. The lens is free to slide in the brass tube D, so that it can be focused on the upper faces of the prism. The field of view is cut down to a circle by a diaphragm E, at the lower end of the tube D.

"Rays of solar light from some uniform source, after passing through the column of water of a depth of 200 mm. placed in tube F, which has a plate glass end, enter the prism A, and emerging, illuminate one-half of the circular field of view. Rays of light from the same source, after passing through the standard solution in tube G, enter prism B, and are totally reflected at its surfaces, and emerging, illuminate the other half of the field of view."

"The colors produced by the absorption of the two liquids can then be readily compared and brought to the same value as follows: The standard solution is held in a glass jar and is connected by means of a glass tube with the standard tube. The top of the jar is furnished with a piece of flexible rubber tubing terminating in an inflating bulb. By means of the latter the observer increases the depth of the standard in the standard tube, which has a total length of 200 milimeters, until the color produced on the field of view matches that of the water in the other tube; he then closes the pinch-cock on the tubing and reads the color of the water from the scale on the standard tube."

With such a colorimeter both the method of varying the depth of the column of water to match the color of a definite depth of standard solution and that of varying the depth of the standard to match the color of a definite depth of water can be used.

Before adopting the method of varying the depth of the standard to match the color of a definite depth of water, already described, a series of careful experiments were made in order to determine the relative accuracy of the two methods. It was found that if the first of the two possible methods is used, in which the depth of the standard remains constant, the depth of water can be varied safely only between certain limits. As the bottom of the tube is approached the change in color, corresponding to any given decrease in depth of water, increases rapidly. With waters varying in color from 0 to 1.00 it was found that at least three standards are necessary in


C
D
F
G
SECTION OF EYE-PIECE.
GLASS TUBE for SAMPLE
GLASS TUBE for STANDARD
GLASS JAR for STANDARD
FLEXIBLE TUBING
PORCELAIN REFLECTOR
INFLATING BULB
SCALE
CENTIMETERS
INCHES
COLORIMETER
FOR
EXPERIMENT FILTER STATION
BOSTON WATER WORKS
WESTERN DIVISION.
Aug. 1892.

order to have a difference in reading of one division (=2 mm.) on a total scale of 200 mm. amount to an error of not more than four per cent.

This is shown graphically in the upper diagram on Plate 2, where the colors obtained by calculation are plotted for several different standards. The depth of water in the tube is represented by the abscissas, and the calculated color when using the standard marked on each curve by the ordinates. The point at which the error in a color reading, resulting from an error of one scale division in reading equals four per cent. is shown by a cross on each of the curves. For all waters having colors darker than this, a new standard must be employed. The necessity of employing different standards for waters having a range of color between 0 and 1.00 makes this method impracticable.

The method of varying the depth of the standard solution to match the color of a definite depth of water was found to give readings of equal value in all parts of the tube, and correct readings of water having color of from 0 to 1.00 were obtained with a single standard, as shown by the following table:

| Color of Standard. | Depth of Sample under Examination. | Depth of Standard in m. m. | Calculated Color of Water. | Color in m. m. for 10 Scale Divisions. |
|---|---|---|---|---|
| 1.00 | 200 millimeters. | 200 | 1.00 | .10 |
| 1.00 | | 180 | .90 | .10 |
| 1.00 | | 160 | .80 | .10 |
| 1.00 | | 140 | .70 | .10 |
| 1.00 | | 120 | .60 | .10 |
| 1.00 | | 100 | .50 | .10 |
| 1.00 | | 80 | .40 | .10 |
| 1.00 | | 60 | .30 | .10 |
| 1.00 | | 40 | .20 | .10 |
| 1.00 | | 20 | .10 | .10 |
| | | 0 | 0 | .10 |

The average of two sets of readings by independent observers of a set of platinum standards in the colorimeter, having the 1.00 platinum standard in the jar, show that the maximum error does not exceed .02. In case greater accuracy is desired for a water having a low color, a 0.50 standard can be substituted for the 1.00 standard in the jar.

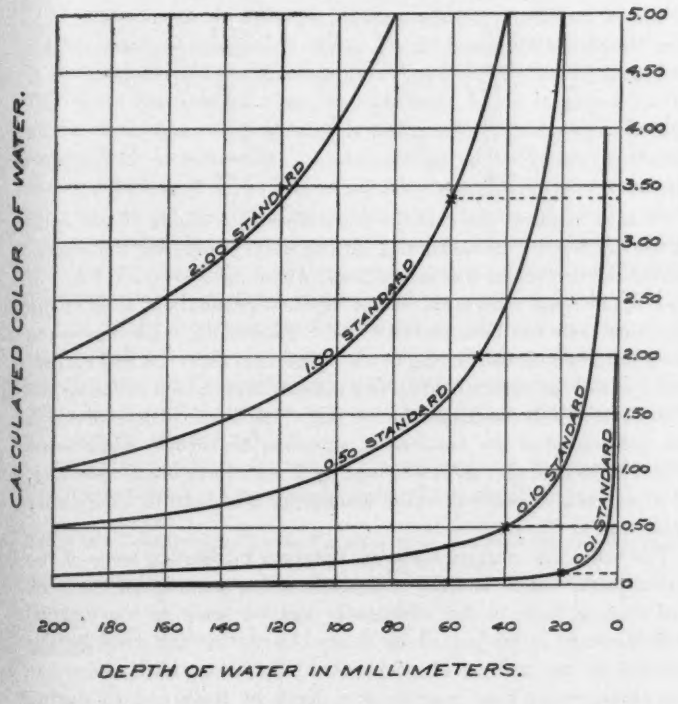
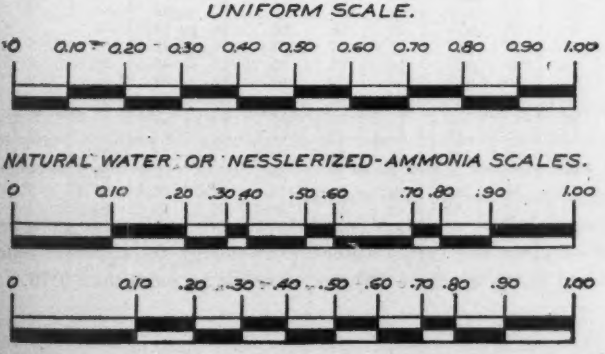

CALCULATED COLOR OF WATER.
2.00 STANDARD
1.00 STANDARD
0.50 STANDARD
0.10 STANDARD
0.01 STANDARD
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
200 180 160 140 120 100 80 60 40 20 0
DEPTH OF WATER IN MILLIMETERS.

PLATE 2.


UNIFORM SCALE.
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
NATURAL WATER OR NESSLERIZED-AMMONIA SCALES.
0 0.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00
0 0.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00

| Platinum Standard. | Colorimeter Reading. |
|---|---|
| 0.10 | 0.115 |
| 0.20 | 0.22 |
| 0.30 | 0.32 |
| 0.40 | 0.40 |
| 0.50 | 0.50 |
| 0.60 | 0.595 |
| 0.70 | 0.70 |
| 0.80 | 0.80 |
| 0.90 | 0.895 |
| 1.00 | 1.00 |

By thus reading the color of the different members of the scale of the nesslerized ammonia and natural water standards, the irregularities of the scales was determined, which are shown on Plate 2. The upper scale represents one of uniform graduation, such as the platinum scale has been shown to be. The middle scale represents the graduation corresponding to the nesslerized ammonia and natural water scales, as determined by two independent observers, using the 1.00 natural water standard in the jar. The lower scale represents the graduation of the nesslerized ammonia or natural water scale which is the average, as determined by three independent observers, of fifteen sets of natural water standards, read both in the Nessler tubes and in the colorimeter.

The following uniform scale was obtained by diluting some of the 1.00 natural water standard to form the lower members of the scale and reading them in the colorimeter against some of the original 1.00 standard in the jar, which shows clearly that the irregularities are due to the method of preparation of the standards and not to any cause arising from varying the depth of the standard during the reading.

| Dilution of 1.00 Standard. | Reading on Colorimeter. |
|---|---|
| .10 | .035 |
| .20 | .21 |
| .30 | .295 |
| .40 | .405 |
| .50 | .52 |
| .60 | .60 |
| .80 | .80 |
| 1.00 | 1.00 |

For reading the color of waters darker than 1.00 it is necessary to use a shorter depth of water for comparison, or perhaps better to dilute with distilled water so as to bring the color within the range of comparison with the 1.00 standard.

I also think from my experience that it is advisable to do so in the case of exceptionally turbid waters, even though the apparent color when read in the depth of 200 mm. may not be more than 0.70.

Such a colorimeter with the platinum standard has been in use in the laboratory of the Boston Water Works from 1892 until 1898 and in the laboratory of the Metropolitan Water Works from January 1, 1898 until the present time, and has been found to give a ready means of reading colors accurately and quickly. The only difficulty experienced is one which is experienced alike by all methods, namely, the variations in hue of surface waters with the season, as such waters are redder in the spring and summer and yellower or even greenish in the autumn and early winter. This we have already seen is due to the nature of the coloring matter present in fresh or old leaves and in vegetable coloring matter.

Opportunity for changing the color of the platinum standards to match such variations of hue of the water is afforded by the fact that the amount of cobalt which imparts the red component of the color, is not a fixed quantity and is to be added in such quantity as will produce the desired hue.

Appended is a table for use in converting color readings on the Nessler or natural water scale to those of the platinum scale.

TABLE FOR TRANSFORMING COLOR READINGS FROM THE NESSLER AND NATURAL WATER TO THE PLATINUM STANDARD.

| Nessler or Natural Water Standard. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | .02 | .04 | .06 | .08 | .09 | .11 | .13 | .15 | .17 |
| .1 | .18 | .19 | .20 | .20 | .21 | .22 | .23 | .24 | .24 | .26 |
| .2 | .26 | .27 | .27 | .28 | .29 | .29 | .30 | .31 | .32 | .32 |
| .3 | .33 | .34 | .34 | .35 | .35 | .36 | .37 | .37 | .38 | .38 |
| .4 | .39 | .40 | .40 | .41 | .42 | .42 | .43 | .44 | .45 | .45 |
| .5 | .46 | .47 | .47 | .48 | .48 | .49 | .50 | .50 | .51 | .51 |
| .6 | .52 | .53 | .53 | .54 | .54 | .55 | .56 | .56 | .57 | .57 |
| .7 | .58 | .58 | .59 | .59 | .60 | .60 | .61 | .61 | .62 | .62 |
| .8 | .63 | .64 | .64 | .65 | .66 | .66 | .67 | .68 | .69 | .69 |
| .9 | .70 | .71 | .72 | .73 | .74 | .75 | .77 | .78 | .79 | .80 |
| 1.0 | .81 | .82 | .82 | .83 | .84 | .84 | .85 | .86 | .87 | .87 |
| 1.1 | .88 | .89 | .89 | .90 | .91 | .91 | .92 | .93 | .94 | .94 |
| 1.2 | .95 | .96 | .96 | .97 | .98 | .98 | .99 | 1.00 | 1.01 | 1.01 |
| 1.3 | 1.02 | 1.03 | 1.03 | 1.04 | 1.05 | 1.05 | 1 06 | 1.07 | 1.08 | 1.08 |
| 1.4 | 1.09 | 1.10 | 1.10 | 1.11 | 1.12 | 1.12 | 1·13 | 1.14 | 1.15 | 1.15 |
| 1.5 | 1.16 | 1.17 | 1.17 | 1.18 | 1.18 | 1.19 | 1·20 | 1·20 | 1.21 | 1.21 |
| 1.6 | 1.22 | 1.23 | 1.23 | 1.24 | 1.25 | 1.25 | 1.26 | 1.27 | 1.28 | 1.28 |
| 1.7 | 1.29 | 1.30 | 1.30 | 1.31 | 1.32 | 1.32 | 1.33 | 1.34 | 1.35 | 1.36 |
| 1.8 | 1 36 | 1.37 | 1.37 | 1.38 | 1.39 | 1.39 | 1.40 | 1.41 | 1 42 | 1.42 |
| 1.9 | 1.43 | 1.44 | 1.44 | 1.45 | 1.46 | 1.46 | 1.47 | 1.48 | 1.49 | 1.49 |
| 2.0 | 1.50 | | | | | | | | | |

DISCUSSION.

In answer to the question as to the cost of the apparatus constructed under the direction of Mr. FitzGerald, Mr. Hollis could give no definite information, but he thought that one could probably be made for about $100. It was specially constructed and to his knowledge it is the only one in existence.

MR. WHITNEY. I should like to ask Mr. Hollis how much skill is necessary in getting a satisfactory or accurate reading of the scale from the instrument?

MR. HOLLIS. Very little indeed. I often have a young man in the laboratory, who does not ordinarily read the colors, check my readings, and he will read to within one division, that is a hundredth of the scale. There is a point, however, in connection with that which should perhaps be mentioned, namely, that two people may not obtain the same color reading of a sample of water owing to the fact that the eyes of one observer are more sensitive than those of the other to some component color of the sample. I have repeatedly found that my eyes are more sensitive to red than those of some people, which occasionally causes the color of a sample of water to appear very slightly darker to me than to another observer.

MR. HASKELL. I would like to ask Mr. Hollis if it is not possible to read as accurately through the small tube filled with the platinum cobalt standard as with this instrument?

MR. HOLLIS. The readings obtained with a set of platinum standards in Nessler tubes are not as accurate as those obtained with the colorimeter as, when standards are used in Nessler tubes, the intervals between members of the set are never less than one-tenth. Between zero and one there are ten tubes representing one-tenth, two-tenths and so on, and any closer reading has to be done by interpolation, while on the colorimeter there are one hundred divisions between zero and one. The colorimeter was devised mainly to eliminate this uncertainty arising from the interpolation between tenths. Each division on the colorimeter is one-tenth of that between consecutive standards as prepared in tubes.

MR. HASKELL. Wouldn't it be possible, Mr. Hollis, for two experts reading samples of the same water by the tubes not to vary over three points? For instance, the standards varying ten points, say from .40 to .50, if you read .43 the other expert would not be very liable to read over .46 or under .40, would he?

MR. HOLLIS. He would not.

MR. HASKELL. That is, the personal error in using the tubes would certainly be within three points.

MR. HOLLIS. We have fixed it at two points as the result of our readings; but of course it is much more difficult to read in that way and it requires a longer time. By the use of this instrument the comparison is made very quickly.

MR. HASKELL. Of course I recognize the beauty of that instrument in doing accurate work, but we cannot all secure one of those as readily as we can the tubes.

MR. HOLLIS. I think three-hundredths would be the maximum variation in reading by the tube method, and it is possible to reduce it to two, as we have found in reading the effluents from the filter tanks.

MR. HASKELL. I would like to ask Mr. Hollis if he knows the depth in Lake Cochituate at which this point of stagnation he mentioned takes place?

MR. HOLLIS. That is a subject I studied very carefully, more particularly in the summers of 1890, 1891 and 1892. The maximum stagnation is quite close to the bottom (60 feet,) but the amount of oxygen begins to decrease, I should say, not very far below the mid-depth, (30 feet.) It seems, however, to depend a great deal on the character of the water and the character of the bottom of the reservoir. I remember examining a reservoir 23 or 24 feet deep for dissolved oxygen and finding at the depth of, I think, 12 feet that the water contained no oxygen whatever. That shows a very rapid disappearance of the oxygen held in the water, because there is but a short interval even during the summer, when there is not sufficient wind to stir the water to that depth.

MR. HASKELL. I didn't fully understand what you said about the color of the water in those two bottles (referring to samples exhibited by Mr. Hollis) and the depth below the surface at which the water was taken. I understood you to say that the color at the surface of the water was .22, and of the water taken at a lower depth, 1.20; am I correct?

MR. HOLLIS. Yes, that is so. It was .22 at the surface and 1.20 at the bottom, but on exposure that which was 1.20 increased to 3.70 on account of the oxidation and final separation of the iron.

MR. HASKELL. Are we to infer from that that the water at

that depth is six times as poor in character as that at the surface?

MR. HOLLIS. I think it would not be exaggerating it at all to say it was six times as poor, because it would be absolutely unfit for use. The water at the bottom during the period of stagnation has a marked unpleasant odor, frequently characterized by hydrogen sulphite, and we have this large amount of iron in solution which would prevent the use of the water, and in every way it is objectionable. On the other hand, don't let me give you the impression, please, that there is any large amount of stagnant water in Lake Cochituate, for that is not so. There is simply a deep hole in the lake where this stagnation takes place at a great depth; there is no possibility of stirring it up, and that is the reason we selected it for study. The water of the lake as a whole is good, and after the over-turn, when all this bad material is brought to all depths, the character of the water of the whole lake is affected but very little, so the stagnation is comparatively unimportant with reference to the water of the entire lake. It simply affords a good opportunity to study what we are liable to meet with in other cases.

MR. HASKELL. I have known a small pond in which the point of stagnation was not over 6 feet below the surface. That is, if a sample of water which showed no oxygen, showed that the oxygen was entirely consumed, I suppose that would be evidence that the water had arrived at a stage of stagnation; and I found that condition in one instance existing not over 6 feet below the surface under the ice. Now, in view of that fact, isn't it probably that in small ponds, where the wind does not have an opportunity to stir the water as it does in blowing across a long pond, there is often a state of stagnation very near the surface, or much nearer, at any rate, than you would find in Lake Cochituate.

MR. HOLLIS. Yes, sir, it is so, and especially in a small swampy pond with a muddy bottom. I have in mind such a small pond which was stocked with carp, and during one winter every fish in the pond died, which I think was undoubtedly because of the lack of a supply of oxygen.

THE PRESIDENT. Are there any more questions to be asked? This is a subject in which I think we are all interested, certainly I am particularly so.

MR. WHITNEY. I have seen a statement somewhere as to the depth of soil which the Metropolitan Water Board decided should

be taken off from the site of the Wauchusett Reservoir, but I have forgotten now what it is, and I would like to ask Mr. Hollis to tell me, if he remembers.

MR. HOLLIS. I haven't seen the figures, in fact I didn't know that they had been definitely determined. But as appears from this article published by Dr. Drown, it is his opinion that an amount of organic matter represented by loss on ignition of one and a half to two per cent. is a safe amount to leave in, because those soils taken from a depth which showed that amount were on the dividing line between those which imparted a great deal of chemical impurity and color to the water and those that did not. He further said that below a depth of 9 to 11 inches, the soil in most localities showed a rapid falling off in the organic compounds. In connection with that I will say that with Dr. Drown I made a very thorough study of the site of the Hopkinton reservoir, and we were not satisfied at that time that the loss on ignition would give satisfactory data, because if there is any clay present all of the water is not driven off at 100, the temperature at which it is dried. We made organic combustions to determine the amount of carbon absolutely present in a weighed quantity of the soil after careful mixing, and from this percentage of carbon computed the corresponding percentage of the organic matter, knowing as we did from microscopical examination the character of the organic matter present. It was largely the portion of the root-stocks represented by the bark, those being higher in carbon than the woody portion, which had almost always decayed away. These experiments were repeated by Dr. Drown, and he found that the measure, as I have given it, of from one and a half to two per cent loss on ignition agreed with what was found to be a safe amount of organic matter arrived at in this way.

MR. HASKELL. Mr. Hollis stated that they gathered a sample of earth and put it to soak, and in a certain length of time it added a certain amount of coloring matter to the water, and that that process was continued for a certain period. I would like to ask him if there was a diminution in the amount of color from time to time, and if it seemed probable that in the not distant future the color-giving material in the sample might have been entirely eliminated, so it would not color the water at all?

MR. HOLLIS. That would certainly be a most interesting thing to find out, but the report, as I think, was given in such a way that

we cannot determine from what was stated whether that would be the case or not. The experiments reported were made in this way. Most, I think all of the samples from open lands and swamps were treated as follows: Fifty grams, or at least a definite amount of soil, was treated with a definite volume of distilled water, with which it was allowed to stay in contact for eighteen hours, a definite period. Then the color was taken and the analysis made. In the case, however, of two, at least, of the samples from land from which a heavy growth of timber had recently been removed, they were treated, not successively, but for a longer time, and the color was read after standing eighteen hours, after standing three days, and after standing a week. Up to the end of the week the color of the sample increased regularly; but they did not try it in the way in which Mr. Haskell suggests, which would be a good way, that is make successive extractions. Dr. Drown's experiments seem to show in the case of leaves that you can go on extracting for quite a long while, and I know my own work showed that that was the case. In the case of logwood, the first extracts are yellow, after which it imparts for a long time a deep purple color to fresh portions of water. I suppose it is only fair to assume that the same is true of most woody matter that holds coloring matter. Of course there is a limit, but it is not easily reached, at least, not in the laboratory. I suppose it might be different in the large volume of water in a reservoir which is constantly at work.

MR. FULLER. I would like to ask Mr. Hollis in regard to filtered water, as to the different depths through which water is filtered, whether the result would depend upon the depth of the filtering material; that is whether the color would decrease in proportion to the depth of the filtering material?

MR. HOLLIS. I think it undoubtedly would, if filters were constructed so shallow that they did not remove the desired quantity. All of those I have in mind, or at least the great majority of them, were built of the depth of about 5 feet, the depth which would be used in practice, and it was a comparison of a large number of different materials rather than different depths, and a study of the rates of flow of each.

MR. FULLER. Five or six feet of filtering material would remove the larger proportion of the color, I suppose?

MR. HOLLIS. A very large proportion; practically all from a colored surface water.

MR. HASKELL. I would like to ask Mr. Hollis if he knows definitely, so he can tell us on the standard of colors, from some of his experiments how thoroughly the color was removed in a proper filter?

MR. HOLLIS. Almost entirely, unless the rate of filtration is very high. For instance, the average color of the water which was taken from the Chestnut Hill reservoir was about .50, and after filtration, it would read perhaps only a few hundredths. The same result has been obtained at Lawrence in the State Board's work.

MR. FULLER. I would like to ask Mr. Hollis if there is a great difference in the tenacity with which the coloring matter is held in different waters, or is it all practically alike? That is, if you had water from different sources of the same degree of color, would it be equally easily removed from all of them?

MR. HOLLIS. I don't know, Mr. Fuller, that I can answer your question definitely. That could only be told from experience with a large number of sources, and my experience has been limited almost entirely to surface waters from the watersheds used by the Boston Water Works. The only other cases that I can call to mind are cases where filters were used for other purposes than for the removal of color, that is the removal of bacteria from a polluted source. I think all of our waters from similar watersheds showed the same result.

MR. CODD. I would like to ask at what time of day the temperatures were taken?

MR. HOLLIS. The temperatures are taken in connection with the collection of samples from our different reservoirs, which I should say was between seven and nine o'clock in the morning. The samples are collected for us once a week at all the reservoirs, at an hour sufficiently early so that they can be taken to a forenoon train and sent to our laboratory. That is particularly interesting just at present when we have cool nights and mornings. If they are taken at the usual time they will very soon begin to fall off in the case of the influent, which becomes cooled down through the night, whereas, if they are taken later during the day they will show higher temperatures.

MR. CHACE. In answer to Mr. Fuller's question with regard to the difficulty of removing the color in different waters, I suppose he is familiar with the reports of the State Board of Health a few

years ago, when the Hyatt Filter Company was flourishing and was deluging up with statements that they could remove the color from any water with one grain of alum precipitate, that, according to the experience of the chemists of the State Board, there were waters in Massachusetts which required 17 grains of alum to remove the color.

MR. BANCROFT. Perhaps I can throw a little light on Mr. Fuller's question. We are running a mechanical filter, and at certain times, when there is apparently no higher color than at other times, although I have made no color tests, it is very much harder to remove the color than at other times. Sometimes, indeed, it would require more alum to remove the color than we care to put in.

MR. WHITNEY. I would like to ask Mr. Bancroft if this persistency of color is particularly noticeable in any month in a series of years, and if so, to what he attributes it?

MR. BANCROFT. It has usually been in the month of June, but this year it was later. I have attributed it to the surface water working down through the peat. We get more iron at that particular time, it is a time when the water is low in the ground, the ground water is low, and we get more iron than we do at high water; and when there is a large amount of iron there is more color as the iron begins to precipitate, although when the water comes out of the ground as it is first pumped there is apparently no more color in it than at other times.

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# THE DESIRABILITY OF MAKING WATERSHED AREAS AND SANITARY DISTRICTS COTERMINOUS.

BY R. E. MIDDLETON, M. INST. C. E., M. INST. M. E.

(FELLOW.)

*(Read at a Sessional Meeting held on April 6th, 1898.)*

As was remarked by Major Flower in his address to the Leeds Congress 1897, the division of the country into watershed areas, for purposes of water supply and drainage, which areas shall be made coterminous with sanitary districts, appears to be very desirable.

The writer pointed out in his paper on the "Pollution of Rivers from an Engineer's point of view," read at the same congress, that rivers and streams have, from the earliest times, been put to two different and antagonistic uses, they have been considered to form the natural source of supply for water to be used for drinking, culinary and ablutionary purposes and at the same time to be receptacles for all animal, vegetable and mineral refuse. It has even been maintained in quite recent years that the latter is the natural and primary duty of every river and stream.

It is scarcely necessary to point out to a Society of Sanitarians that the first use of a river is to provide water for animal life. Secondly it may provide power for grinding corn, for the weaving of fabrics, and for such other purposes as may be beneficial to the riparian inhabitants. Thirdly it may be used for carrying the persons and property of those who live near it, and the necessaries of life from point to point. Lastly and not until the other requirements have been satisfied, it may be used, in a manner which shall not defeat its primary obligations, for the removal of refuse matter.

Needless to say the requirements of a crowded population and of an advancing civilization have materially altered the second and third items of legitimate use, mills are in many cases built and

worked, not for the supply of the necessaries of life to the inhabitants in its immediate neighborhood, but for the production of goods to be supplied, perhaps to distant countries, the only benefit accruing to the people of the district being found in an increased demand for labor and consequent circulation of money, the riches produced being diffused over a large area.

It frequently happens that manufacturies which originally depended on water for their motive power, have found the supply inadequate and unreliable on account of its intermittent character and resort has been had to steam, whereby a portion of the water has been taken from the river and has been diffused into the atmosphere as vapor, also the use of the water has not been limited to power, but large quantities have been employed for the cleansing of foul rags or other articles for mixing with materials used in the processes of manufacture and for the removal of chemicals from partially manufactured goods.

Advancing civilization, especially in respect of rapidity and facility of transport, has both enabled and obliged the manufacturer to locate his business in a position where the supply of raw material with which he deals can be obtained most easily and therefore most cheaply, where wages are low and where motive power is cheap.

As the land of the country will no longer supply sufficient corn for the consumption of the population, and as each year brings a larger and larger supply of cereals to our shores from foreign countries, flour milling is no longer so profitable a business, when conducted under the old conditions on small rivers, as it was in former times; larger mills and more elaborate machinery are now required for the production of the fine and white flour which is now used almost universally, the old fashioned flour or wind-mill is becoming obsolete, and is being replaced by modern mills driven by steam power and situated near a sea-port.

On the other hand processes of manufacture, which require large quantities of water for cleansing purposes, are increasing, and the mill which, in the old days, provided food for its district, has become a source of pollution in itself, and a centre of pollution on account of the population which has grown up around it and which is dependent on it.

In every direction we find the tendency to pollute is on the increase, at the same time that the demand for a supply of pure water is likewise increasing, while the area from which a supply can safely be drawn is diminishing and many rivers have become impossible as sources of water supply, in all cases on account of the amount of trade refuse which has been passed into them.

In the mining districts the banks of the rivers and streams become tip heaps for ashes and scoria, often containing poisonous ingredients, all sorts of refuse are thrown into them, they stink and are corrupt, but filthy as they are they are not so offensive as are the waters which are used for washing rags, or woollen goods, for cleansing skins, or the waters that are near large breweries.

Undoubtedly the pollution which is most dangerous to man is that produced by man himself. The untreated excreta of the human being are at all times a source of danger, but when they proceed from a diseased human being they may carry with them the germs of death to many fellow creatures, and with the increase of population comes increasing difficulty and increasing costliness in dealing with the refuse, animal, vegetable and mineral, which results from human aggregation.

It seems to be doubtful if any danger is to be feared as resulting from the droppings of cattle when living in the open, and even if they are to some extent dangerous they are necessarily limited in quantity, for cattle cannot live in an area which will not easily disinfect all the manure which they produce.

Probably the artificial manures, if one may thus designate guano and fish in a putric condition, are much more to be feared than any natural manures; the fish are, however, in themselves, so offensive to the sense of smell that they are seldom used except for very high cultivation, such as hop gardens.

An endeavor has been made to point out in a brief but effective manner the causes which are producing an increased use of water for the supply of steam to engines, for cooling and other purposes in iron and steel works, for the cleansing and manufacture of the materials used in paper-making, fell-mongering, woollen and linen manufacture, brewing, in chemical works, and in a thousand other ways, much of such water being diffused into the atmosphere as vapor, while still more is so befouled as to be unfit for drinking, culinary or even for washing purposes.

In another direction the available water supply is also becoming more limited on account of the amount of land which is occupied by towns, villages and manufacturing centres, while both the increase in population, the demands of a higher civilization and the greater requirements for steam and similar uses, all call for a greater supply and a more liberal use of water.

Consequent on the increase in the size of our large towns the demand for water has led to an upsetting of all preconceived ideas as to the sources from which supplies should be obtained. Manchester obtains a supply, not from its own district but from Cumberland, Liverpool from Vyrnwy, Birmingham from the Elan Valley, and the London County Council would have us look to the Valleys of the Usk and Wye for our supply of water, and there does not at the present time seem to be any efficient conservation of the sources of supply for the use of those who are the natural heirs to it, namely those who are the first to receive it from the atmosphere and at whose feet it is running, either above ground in the form of streams, rivers and lakes, or below ground in tiny rills. Every town or village situated on the banks of the river or one of its tributaries has a vested interest in the maintenance of the purity of the water which flows towards it. Even if it does not obtain its water supply from the river or stream, still the fouling of the stream or river is an injury to the place, as causing a nuisance palpable to the sight or smell. At the same time, the same population desires to discharge its refuse into the same stream and to become a nuisance to its neighbor lower down on the course of the river.

It would appear on the face of it that the village situated nearest to the source of the river would have the best of it, for its inhabitants would be able to drink pure water while they would befoul what passed them by, and the population of places lower down on the course of the stream would each get a worse sample than the last and would pass it on in a still worse condition than that in which it came to them. Natural causes, the principal of which are, dilution by increase in the volume of the river, oxidation by air and light, the action of vegetation and sedimentation, tend to counteract the influences referred to, and unless the pollution is excessive in quantity the water becomes purer in the lower reaches of the river, rather than the reverse; and many streams which are de-

cidedly impure near their sources are purified before the water arrives at the lower reaches of the river.

The protection afforded to the consumer by the natural processes indicated above are not sufficient, unless they are supplemented by the power of an authority strong enough to curb the tendency of the human animal to get rid of the refuse which he creates, either as manufacturer or as an individual, with the smallest amount of trouble and at the minimum of cost. The disposal of sewage matter was, until quite recently, a subject not to be mentioned to ears polite, the matter was to be hidden away anyhow, so long as it was out of sight; so it was turned into cesspits, the positions of which were often forgotten, or into rivers, to be a nuisance to somebody else. Suddenly, sanitary science became rather the fashion than otherwise, and everybody talked of drains, with the usual result that much was done in a hurry which would have been better done if it had been longer thought over. Most large towns which can afford to spend money pretty freely have made efforts, at any rate, but with moderate success, to get rid of their sewage decently, and not to be greater nuisances to their neighbors than they could reasonably help, but the sewage disposal works of many small towns and villages are practically useless, because the inhabitants have not the money to keep the works for which they have paid, in order. In still other cases, sewage disposal works are conspicuous by their absence.

The selfish policy of turning all refuse into the nearest stream led to greater and still greater pollution of the water supply as time went on, and population and manufactures increased; the natural course of procedure which puts the provision of a pure and sufficient supply of water first and the disposal of sewage second was reversed, and the position became intolerable; moreover, the earlier efforts of legislation were directed to the provision of sewage disposal, while omitting to require that this necessary stipulation should be preceded by an ample supply of water.

Subsequent legislation has inclined to leave the cart before the horse and to subordinate any question of water supply to that of sewage disposal, making the latter compulsory, while the former is to a large extent permissive.

Consequent on this inversion of obligations the Rivers Pollution Act of 1876 is exceedingly tender in dealing with vested interests

in sewers and in the pollution of streams, and experience has shown that it is entirely insufficient to curtail the increasing tendency to pollute, notwithstanding the precautions which have undoubtedly been taken in many cases to prevent it. Later Acts have not, except as regards special localities, provided any adequate cure for the evil and then only within the last few years and in the face of the most convincing evidence and in cases of absolute necessity.

Considering the constitution of the authorities which have to administer the Acts dealing with the provision of water supplies, with the disposal of refuse and the pollution of rivers, it is scarcely to be expected that the result should be otherwise than it is. It has been easier for the authority to get water from some other source, however limited its area, however doubtful its ultimate purity, than to face the difficulties of dealing efficiently with the sewage which the same authority must get rid of. All authorities have had conflicting interests to consider when dealing with river pollution, and in all cases the preservation of the river in its pristine purity has been subordinated to the requirements of mill owners, for power purposes, of canals, for purposes of navigation, and of towns and villages desirous of getting rid of their refuse in the most summary manner and at the least possible cost, without consideration of any habitations placed below them on the course of the stream.

In this manner enormous drainage areas are becoming useless for purposes of water supply, and large towns are compelled to tap distant and at present unused and uncontaminated sources of supply, though at great cost, and are rapidly taking from unoccupied districts the water which at some time may be wanted for the inhabitants themselves. The future centres of the industries of the country cannot be predicted with any certainty. Already within the memory of man great cities have sprung into existence where formerly were only villages or desolation.

It seems reasonable that each district should supply its own needs, both in respect of water supply and sewage disposal, but this cannot be done unless water supply, a pure water supply, be put first and sewage disposal be subordinated to it by rigorously enforcing the obligations consequent on the aggregation of large bodies of men in centres of industry.

It is scarcely to be expected that the authority which desires to discharge the refuse of its district into the stream, (and as it draws its water supply from a point higher up does not injure itself,) should be urgent in the prevention of the pollution of the river for the benefit of towns situated below it on its course and in which it has no interest.

It frequently happens that the difficulties in dealing with the sewage of a particular district are enormous, while the question of disposal would become quite simple if compulsory amalgamation were possible.

As has been very ably pointed out by Mr. Malcolm Paterson, M. Inst. C. E., in his pamphlet on "Compensation Discharge in the Rivers and Streams of the West Riding of Yorkshire," the system of compensation in water generally adopted is not by any means universally advantageous, even to those for whom it is provided, while it is destructive of the purity of the river. Mills which only work by day desire to have compensation water delivered to them during the day only, so that they may get the utmost advantages from it, but, as the water is delivered from the compensation reservoir which is situated near or at the head of the stream, the mill nearest the reservoir is the only one which gets the full benefit, while those which are situated further from the reservoir must either work abnormal hours, standing idle in the morning, or they must have sufficient reservoir capacity of their own to conserve the compensation water received during the night and use it in the morning, up to such time as the new supply from the compensation reservoir reaches them. Take the case of a mill situated twenty-four miles below the reservoir, the stream from which travels at three miles an hour and begins to flow at 6 a. m. The new supply does not reach the mill until 2 o'clock in the afternoon, and eight hours' supply must be stored at the mill if the miller is to get the full benefit of the supply.

During the night, at points near the reservoir, the stream is probably nearly dry, and any sewage passed into it must, when added to the decaying vegetation consequent on an intermittent flow, cause a nuisance. At points lower down the river this state of things exists during part of the day as well as during part of the night, and becomes even more objectionable.

Enough has, it is thought, been said to show that if areas of water

supply are to be efficiently safe-guarded, if rivers are to be preserved from pollution, if the mill-owners are to obtain the utmost benefit of the power at their disposal—but without injury to the general interests of the population,—and if the navigation, if there be any, is to be maintained, the present system of divided authority should be abandoned, and a combined and general policy should be substituted for it.

At present every authority is in conflict with its neighbor, conflict in interest if not in fact, and litigation and disagreement are too frequently the result.

There are, it is believed, cases where districts have benefitted greatly by the adoption of combined systems of drainage, as for instance in the case of the Rhondda Valley and the Pontypridd combined drainage. Here, instead of each district providing its own sewage farm, a difficult and somewhat dangerous proceeding in a valley of but limited area, the sewage of the towns in the Valley of the Rhondda, and in the Valley of the Taff from Aberdare to Cardiff, is carried in iron pipes down the valley of the river Taff, and is discharged into the Bristol Channel above the town of Cardiff. This work was, however, carried out entirely in one county, and it may not unreasonably be supposed that unless there had been a County Council having an equal interest in the whole drainage area of the Taff, the District Council of Ystrad-y-fodwyg, the Urban Sanitary Authority of Pontypridd, and the other parties interested in the disposal of the sewage might have been endeavoring to work each their own little sewage farm, to the discomfort of their neighbors, or might have been disputing between themselves without making any progress.

The three Ridings of Yorkshire, being of such large area, are intersected by considerable rivers which flow for the whole or nearly the whole of their courses through one county only, and here again, as might be expected, we find the County Councils taking considerable interest in the rivers which are their own undivided property, an interest which appears to have secured to the general public, to judge from the reports contained in Mr. Paterson's pamphlet, considerable advantages.

Most of our larger rivers, on the other hand, serve as boundaries or divisions between counties. For instance, the watershed of the Thames extends over 15 counties or parts of counties in which some

2,600 authorities, County, Borough, District and Parish Councils hold sway. The whole of these do not have jurisdiction within the watershed, but if the number given above be reduced by 20 per cent., or to 2,080, this figure will probably represent the number of authorities within the drainage area of the Thames.

The watershed of the Severn affects 12 counties and some 1,316 Councils.

The Cambridgeshire Ouse touches 8 counties and some 1,200 Councils.

There is no necessity for carrying the calculation further, but from the figures which have been given some idea may be formed of the conflicting interests existing in any watershed area.

A further consideration which appears to point in the same direction, namely, to the necessity for having some authority responsible for watershed areas, is that of floods. There are many districts in England which are periodically flooded with very disastrous results. While the floods last and immediately afterwards, there is great talk of what could, should and must be done, but it ends in talk, because the interests are so conflicting that before anything can be decided on, the matter has become ancient history, and the public mind has to be stirred up again by another flood, and still nothing results unless there is an authority with sufficient power and possessed of sufficient funds to enable it to deal with the question without directly touching the pockets of the ratepayers.

As has been pointed out, the Rivers Pollution Act (1876) does not provide powers of sufficient stringency to enable the pollution of rivers to be dealt with efficiently, and necessity has obliged certain existing authorities to apply for an extension of their powers, as in the case of the Mersey and Irwell Acts of 1892, and the Thames Conservancy Act of 1894, but these acts are purely local and it seems desirable that they should be made general and that an authority, in some respects similar to the Thames Conservancy Board, but with more expanded powers as regards the raising of funds, should have charge of each of the principal rivers in the country.

The Thames Conservancy Board before 1894 had only power over the tributaries of the Thames for ten miles from their junction with the main stream, and they could only deal with pollutions under the general acts, the operation of which was found to be tedious and ineffectual. They have, by the act of 1894, authority over the

whole of the watershed, and they can enforce their powers much more effectually than under the general law, by means of the following clauses:—

93. If any person does any of the following things, namely:

(1) Opens into the Thames or into any tributary any sewer drain pipe or channel whereby sewage or any other offensive or injurious matter whether solid or fluid shall or is likely to flow or pass into the Thames or into such tributary;

(2) Wilfully causes or without lawful excuse (the proof whereof shall lie upon him) suffers any sewage or matter aforesaid to flow or pass into the Thames or into any tributary down or through any sewer drain pipe or channel not at the passing of this Act lawfully used for that purpose;

he shall for every such offence be liable to a penalty not exceeding one hundred pounds, and to a daily penalty not exceeding fifty pounds.

94. (1) Whenever any sewage or matter aforesaid is caused or suffered to flow or pass into the Thames or into any tributary then, and in every such case, even though such sewage or matter aforesaid had been lawfully so caused or suffered to flow or pass before the passing of this Act, the Conservators shall give notice in writing to the person causing or suffering the same so to flow or pass requiring him within a time to be specified in such notice, but not being less than three months to discontinue such flow or passage.

(2) Provided that the Conservators may if they think fit at any time, and from time to time extend the time specified in such notice by another notice in writing.

(3) And provided that if any person to whom any such notice is given thinks himself aggrieved by reason of the time allowed either by the original or by any subsequent notice not being sufficient, he may not later than one month before the expiration of the time so allowed by writing delivered to the secretary demand an extension of such time, and in case the Conservators refuse to comply with such demand, the question of such extension shall be referred to an arbitrator appointed by agreement or failing agreement by the Board of Trade on the application of either party.

(4) Any person to whom any notice is under this section given by the Conservators shall notwithstanding anything in any other Act within the time allowed by such notice subject to any extension of

such time as in this section provided, discontinue the flow or passage of the sewage or matter to which the notice refers, and in default of so doing shall be guilty of a misdemeanor and be liable on summary conviction thereof or on conviction thereof on indictment to a penalty not exceeding one hundred pounds, and to a daily penalty not exceeding fifty pounds.

(5) Provided that notwithstanding anything in this Act or in any Act incorporated therewith any proceeding in respect of such a misdemeanor may be removed by certiorari into the High Court.

The same authority has also, quite recently, given considerable attention to the prevention of flooding.

In what manner the watersheds should be mapped out, whether the existing boundaries of Counties, Sanitary Unions, and Parishes should be adhered to, or there should be a general re-arrangement of these artificial divisions, is too large a subject to be dealt with in a paper of this character, time will not permit of the full consideration of so difficult a question.

The constitution of the proposed authority is also a matter of great complexity, especially as regards the method of raising the funds to be placed at their disposal, but it may be said that the body should represent every class and interest, and that its duties should consist in the conservation of the river, its banks, and navigation, if any, in the maintenance of its purity including that of its tributaries, in the encouragement of combination and efficiency in sewage disposal and in the prevention of floods.

The writer has endeavored to lay before his hearers a question which he considers to be of considerable importance but which contains the elements of much complexity, and he trusts that the members of the Institute will be able to throw more light on the subject.

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MR. BALDWIN LATHAM (London) said he thoroughly agreed with all that Mr. Middleton had said in his most interesting and instructive paper. The question of controlling watershed areas, especially with regard to the purity of the water supplies of the people, was one of paramount importance. Every day one was brought into contact with the fearful consequences that arise from the pollution of drinking water, and indeed, he began to think there was no question from a sanitary point of view which is of

more importance than that of the water supplies of this country. When he said water supplies, he did not mean to confine himself simply to the surface streams, but to direct attention to a greater extent to those underground streams, which, being out of sight were often out of mind, the consequence being that they were polluted to a frightful extent in the immediate vicinity of the places from which the water supplies are drawn. In fact, it appeared that nearly all the epidemics of typhoid which have occurred in this country, with slight exceptions, have been traced to these underground sources of supply. These had been polluted and had never seen the light of day, which no doubt to a very considerable extent tends to destroy the germinal matter—so fruitful a source of disease. How this matter was to be dealt with was certainly a very large question. Sanitary authorities themselves and water authorities did not seem to appreciate the importance of securing a pure water supply. Only last year a bill was actually introduced into Parliament for making a reservoir in a small town in Sussex, where the overflow of the cesspools passed into the stream above the site of the proposed reservoir, and although that fact was pointed out to the committee, the bill passed. A fortnight previously a bill was brought before the committee of the House of Commons for the establishment of a gas works at Margate, and a most extraordinary position was selected for this gas works—in close contiguity with the aqueducts of the principal water supply of the town, which were only from 60 to 70 ft. below the surface of the site where the gas works were to be erected; yet that bill was passed. When our legislators seemed to so little understand these questions of the importance of the purity of a water supply, and the great danger which is likely to arise from pollution, either in the distribution of the supply or the injurious properties which may be imported at its source, they could not be surprised that there were so many small communities throughout the country which did not regard the question of the water supply from any favorable point of view. They looked upon engineers who advised them that the purity of a water supply was a paramount necessity as having a crotchet, and very often said, "Well, the supply was good enough for our fathers, surely it is good enough for us." That was the answer given to any question as to the pollution of wells which exist pretty well in all the villages and towns of this country. It

was, however, a great question, and they were indebted to Mr. Middleton for having brought the matter under their notice so clearly and concisely. Of course, some watershed areas were very large, like that of the Thames, others were of comparatively small area. Wherever he had anything to do with the formation of districts, he had always drawn the boundary at a watershed line; but where watershed areas pass through two or more counties they were met with great difficulties. For they were told under recent Acts it was almost impossible to take part of a district which belongs to one county and put it under the jurisdiction of a sanitary authority which principally governs in another county. That, however, had been done recently in a case where a district had been taken out of one county and put into another, and he did not see that what had been done in that small way could not be done to a very large extent throughout the country. There was no reason whatever why they should confine themselves to the present arbitary boundaries. A watershed area formed a very good natural boundary, certainly for drainage purposes. The difficult question was in regard to the large areas—an authority to pass over nearly 6,000 square miles in the Thames area would be a sort of legislative body in its government of such a large part of the country. But there was no doubt the principles of watershed areas should be kept in view in the formation of all new districts, and not so much as had been the old boundaries of parishes, which were not properly defined, or served any useful purpose in regard to the engineering work to be carried out within the district they made. It was therefore a question which needed full investigation.

MAJOR LAMOROCK FLOWER (London) observed that he was very much obliged to Mr. Middleton for having brought forward this old idea of his of treating the watershed area as the proper boundary for a sanitary district, and he was equally glad that Mr. Baldwin Latham had drawn attention to the absolute absence of control over subterranean supplies. He contended that no Conservancy Board is complete which has not control over the subterranean water. At the present moment there was no Conservancy Board, nor was there any authority beyond the common law which had any power to prevent the pollution of subterranean water. With regard to the division of the country into watershed areas, it was

no doubt surrounded by a vast amount of difficulty, but a Vice-President of the Institute, Sir Francis Powell, had introduced into his Rivers' Pollution Bill of this year a clause which provided for committees to manage this very question — committees to be formed out of the existing County Councils. It has been said that if the watershed area was made the boundary of jurisdiction it would create a new authority, but he contended that no new authority was necessary at all. It was simply a combination of certain portions of the existing authorities for definite purposes, and therefore he thought the question of dividing the country into watershed areas for the purpose of preventing pollution of water was an exceedingly simple one, and only required to be thoroughly thought out by people who know what they are about to be carried into effect. He did not allow the word "impossible" to be in his vocabulary, for nothing in reason was impossible, and he did not see why this idea could not to be carried out thoroughly and entirely. He believed that the chairman, with his large knowledge and valuable experience, would be able to support the idea so ably brought forward by Mr. Middleton.

Dr. A. Haviland (Farnborough) agreed that they were indebted to Mr. Middleton for having brought forward this subject in the able way he had done. The chairman might remember that more than twenty-seven years ago, when he (the speaker) first commenced his investigations with regard to the geographical distribution of disease in England, he had made the remark in his first work that a natural system should be adopted instead of the artificial one which now exists and defaces our maps of registration districts. There could be no doubt that unless the different areas occupied by the catchment basins of the different rivers and their tributaries be under control, and so managed as to be capable of doing good instead of harm as at present, statistical accuracy was impossible, because there were conflicting interests in one registration district. If a natural system were adopted they would know exactly how to apportion their statistics, and would be able to see what watershed areas ought to bear the burden of disease that their polluted waters engendered. In fact, it was the only scientific method of using the statistics to anything like good purpose. Those who had followed the reports of the Commissioners appointed to investigate into the

pollutions of rivers would remember the excellent map of the Thames basin which the chairman (Mr. Symons) brought forward in his evidence. Lately he had had occasion to compare that map with its natural boundaries of the water partings with the boundaries of the registration districts, and if they were to see how thoroughly opposed to anything like reason those registration district boundaries were, they would be at once convinced of the abnormity of the whole affair, and wonder how in this nineteenth century such a state of things could be permitted to exist. All catchment basins where floods are known to occur should certainly he under one authority that would be able to consider the best means to prevent those floods. Then, too, unless they had these natural boundaries it was impossible to show how certain areas conduced to certain climatic conditions, and those climatic conditions to certain diseases. Therefore from a medical and geographical point of view he certainly upheld the suggestion that the natural boundaries should be resorted to instead of the artificial boundaries. In France they had a much more natural system: they took the boundaries formed by the rivers for the most part and named the departments after the rivers. The Isle of Man was divided into certain sheddings which comprised certain parishes—about three or four in each; shedding means water parting, and those sheddings were marked out by the original inhabitants of the Isle of Man according to the catchment basins of the different rivers. It was remarkable how easy statistics were made for that island compared with what they are for England. As a student of medical geography, he could say that his experience from the very first in 1868 led him to conclude that we shall not arrive at anything like what we want to arrive at—scientific fact—unless we had a natural system of boundaries.

THE CHAIRMAN (Mr. G. J. Symons) pointed out that the delivery of compensation water had been fought a great deal, as to whether it should be sent down during working hours or whether it should be sent in a continuous flow. It seemed to him that it did not matter much what was put into an Act of Parliament, because all depended upon how big the lodge is at the top mill on the stream. If the top miller had storage for twenty-four hours' supply he could just please himself, he was master of the situation;

and half a dozen Acts of Parliament could not prevent him. The County Councils, especially the Yorkshire Council, had taken a great interest in the matter and he was not saying one word against them. All wished that to be done which is best, but it seemed to him that the occupier of the top mill was monarch of the situation. Then there was the question of floods which had so many conflicting points. The ordinary sanitarian and the ordinary Britisher had a great idea that a flood is a nuisance, and a thing that ought to be avoided. In a great many instances farmers rather enjoyed them than otherwise, and instead of getting the sympathy of farmers in their attempts to prevent them they got the other thing. He thoroughly agreed with Mr. Latham in his remarks about the pollution of underground water, but he was surprised to hear him say that he thought that all the principal epidemics of typhoid were traceable to underground water. His own impression was that a good many of them were due to milk. In his own neighborhood there was one such case, and he had heard of many instances arising in the same way. As to the rectification of county boundaries he was rather amused at one thing. Mr. Middleton had brought the question forward, Major Flower claimed to being its father, and somebody else had suggested Mr. Haviland, while in former times it was an idea which he (the chairman) had. So it must be right as they all had chosen it. But the question was, how was it going to be carried out? One of the disadvantages of living in an old country like England and Wales, was that things were crystalized for so many years, before watersheds were thought about. He did not know how their ancestors selected the county boundaries, but water partings had next to nothing to do with it. He did not attach serious weight to the difficulty of dealing with large areas, like the Thames and some of the other rivers, say, the Severn, because he could see no reason why they should not be cut up into subsidiary ones, and then be perfectly manageable. The difficulty was their being in a very old country where it was difficult to move. There was such a number of vested interests in the way. Mr. Latham described one bit of good work in which a part of a county was chopped off and transplanted into another, and probably hardly anybody knew anything about it till it was done. In Scotland he was glad to say the same process was going on. The Scotch counties were formerly distributed in a way that

made them very worrying to a school boy, and now nearly all those detached portions were being transferred by some Act of Parliament, and gradually absorbed by the counties in which they were situated. Like everyone else he had thoroughly enjoyed Mr. Middleton's paper and did not know that he had any criticism to answer, for there had been nothing but praise.

MR. MIDDLETON, replying to some of the points raised, said he was obliged for the way the paper had been received. He did not pretend to be one of the fathers of the idea at all, for he thought it was older than he was, but it was one of the old things which was none the worse for a little keeping—which must be impressed upon people over and over again. As the chairman had said, this was an old country and required a good deal of stirring up to get alterations, especially in matters of sentiment. Up to recently, the boundaries between counties had been questions affected by sentiment—the people of Suffolk looked upon a Hampshire man as a foreigner who did not belong to the same country at all, and there were parts in the north where a Londoner would not understand what the people were saying. But steam locomotion had largely changed that, the rapid travel of today was producing a still more rapid change in the country at large. Sentiment was largely dying out, though there was a sort of attempt to maintain it in the territorial regiments, but he did not think that had been very successful so far. As time went on it would be more easy than it had been in the past to get people to see that the boundaries between counties had in some cases been mere matters of sentiment, and that a great many of them could be improved very much, not only with advantage to the inhabitants themselves, but with still greater advantages from a sanitary point of view. There could be no question that the present divisions were injurious to many sanitary schemes and water supplies. It was often impossible to carry out a good scheme to prevent the pollution of water, because one of the parishes thought it was not the right thing to do, or sewage had to be discharged from one parish into another, where there was opposition. With regard to the size of the area, they now had the Thames Conservancy which had been given a certain amount of power over the whole of the watershed area of the Thames, which covered some 6,000 square miles. He did not say that the power

which was put into the hands of the Thames Conservancy was a sufficient power, though it was considerable, and would have a great influence on the future of the Thames basin. One of the greatest difficulties, both in regard to the Thames Conservancy and any other Conservancy or Council for the conservation of the watershed of any river, was the question of funds. The Thames Conservancy were fortunately able to get a considerable amount from the London Water Companies, and a great deal of their work which was done for the benefit of London in the way of keeping the river pure for the supply of that city, was done at the cost of the water companies. But in most other places there was no fund available for the use of the Conservators of the river, and the rate-payers strongly objected to be rated directly for any such purpose. Those below said they were only flooded every now and then, and that it was not worth while; those higher up were not flooded at all, and did not think they were the ones to pay for the benefit of those lower down. The only way out of the difficulty was for the whole district to pay and the rate would be so infinitesimal that it would be scarcely calculable, nobody would feel it at all. Some means of that kind would have to be found for providing sufficient funds for preserving rivers from pollution, and also in regard to the almost equally important question of flooding. Up to lately the Thames had suffered in some cases greatly from floods. Not many years ago Taunton suffered from a serious flood, which was all the worse because timber happened to be stored beside the river and stuck in the bridge, with the result that the lower part of the town was flooded to a considerable depth. Taunton was then going to do many grand things, but they eventually did nothing. In other parts identical cases could be quoted, and he supposed the periodical floodings would continue until they got some such Board as he had mentioned. It was true that farmers on the banks of the rivers liked their land occasionally flooded, but not to any great depth, for they did not care to have their fences washed away or anything of that kind. But if it was a flood which passed two or three inches over the land and left a sediment behind, they did not mind. This, of course, could not always be provided for. If they were approached immediately after a flood of 5 or 6 ft. they would be quite ready to pay for their prevention. Apart from that, the farmers were not the people to

be considered, because it was not the farmers only who suffered from floods but the people in the towns and villages, sometimes seriously, both in pocket and comfort. The difficulties in the way of providing a proper authority were very great. He did not think an amalgamation of the Councils for such an area as the Thames would be satisfactory, for it would simply mean a shifting of responsibility and liability, the same people would be concerned, who, if they met at separated Councils would only fight still more. He did not think that would be a good and final representation, but what would be the best representation he was not prepared to say at the present moment.

# ABSTRACT FROM THE REPORT TO THE EXECUTIVE BOARD, ROCHESTER, N. Y.

BY E. KUICHLING, CHIEF ENGINEER OF WATER WORKS.

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## THE OLD CONDUIT.

The old conduit from Hemlock Lake to Mt. Hope reservoir was constructed during the years 1873, 1874 and 1875, and is divided by the storage reservoir at Rush into two principal sections. Excluding the 36-inch intake pipe at the lake, the first or southern section embraces 50,807.3 ft., or 9.623 miles, of 36-inch wrought-iron riveted pipe made of plates 3-16-inch thick; 15,446.5 ft., or 2.925 miles, of 24-inch wrought-iron riveted pipe made of plates 3-16 and 1-4-inch thick; and 36,009.9 ft., or 6.820 miles, of 24-inch cast-iron pipe of varying thickness, according to the water pressure; total length = 102,263.7 ft., or 19.368 miles, from the mouth of the pipe in the gate-house at Hemlock Lake to its end in the submerged influent well of Rush reservoir. * * * * *

The discharge of the old conduit was gauged twice last year at Rush reservoir, the first measurements being made on June 22–24, and the second on November 9–10. Owing to the failure of securing means for completing the permanent connections of the conduits with the two reservoirs, it is still necessary to make all such measurements in a very tedious manner by carefully observing the rise or fall of the water service in Rush reservoir, as well as the evaporation therefrom, during a period of eight hours or more, and then ascertaining the rate of leakage of the reservoir as soon as possible afterwards. In the southern division of 19.368 miles, from the lake to Rush, the delivery of the pipe is determined by the rise of

the water in said reservoir after closing all outlet valves therefrom, while in the northern division of 8.879 miles from Rush to Mt. Hope, it is determined by the fall of the water surface caused by the relatively greater discharging capacity of the northern portion of the conduit, as it is not deemed expedient to subject the southern division unnecessarily to full hydrostatic pressure by closing the inlet valve.

The results of these complicated gauging operations were as follows: On June 22–23, during a period of 22.5 hours, and on November 9, during a period of 5.5 hours, the discharge from the southern division was at the rate of 6,598,400 and 6,675,900 gallons per day respectively; while on June 23–24, during a period of 22.25 hours, and on November 10, during a period of 8 hours, the discharge of the northern division was at the rate of 7,887,800 and 8,153,400 gallons per day respectively. Comparing these figures with the similarly observed discharge of 7,185,000 gallons per day for the southern division on October 10, 1890, and that of 8,392,700 gallons per day for the northern division on September 25, 1892, a very marked reduction of delivering capacity, amounting to about one per cent. per year on the average, will be noticed in both divisions, which is probably the result of accumulations of rust, sediment and organtic growths on the interior of the pipe. A further comparison can also be made with the gaugings of the southern division, made early in 1876 by the late Mr. L. L. Nichols, C. E., which then exhibited a discharge of about 9,000,000 gallons per day, thus showing that such reduction has been progressive or continuous during the whole period of twenty-two years. Owing to lack of reliable data, no good estimate can be made in regard to the future rate of this diminution of flow, but from such observations as have been made here and elsewhere, it is very probable that it becomes smaller each year, instead of increasing.

## THE NEW CONDUIT.

The new conduit from Hemlock Lake to Mt. Hope reservoir was constructed in 1893 and 1894. Excluding the intake pipe and gate-house at the lake, it consists of a brick conduit of horseshoe-shaped cross-section, 6 ft. high and wide inside, and 11,892 ft., or 2.252 miles long, terminating in an overflow chamber 34 ft.

long, the north end of which forms the beginning of a 38-inch pipe conduit 138,260 ft., or 26.186 miles, in length to the new gate-houses at Rush and Mt. Hope reservoirs. Of this latter length, 136,948 ft. is 38-inch riveted steel pipe made of plates $\frac{1}{4}$, $\frac{5}{16}$ and $\frac{3}{8}$-inch thick, and 1,312 ft. is 36-inch cast-iron pipe and special castings distributed at various points. These distances are measured along the axis of the pipe from its beginning near Hemlock Lake to the middle of the by-pass branch casting in the new gate-house at Rush reservoir, thence to the middle of a similar casting in S. Clinton street near Elmwood avenue, and thence to the east face of the foundations of the new gate-house at Mt. Hope reservoir; the additional lengths of pipe and castings laid beyond the said branch in S. Clinton street, and also in the two gate-houses for reservoir connections, are therefore not included in the above figures. * * * * * * * *

The gaugings of the discharge of the middle or second section of the new conduit, to which reference was made in the Report of the Executive Board for 1896, were repeated last year; and as such reference contains several numerical errors, advantage is taken of this opportunity to correct them. The observations were carried out essentially for the purpose of determining the discharge at different degrees of opening through the 8-inch by-pass valve of the main 36-inch inlet valve at Rush reservoir, this being the means by which the flow into said reservoir is temporarily regulated, owing to the failure of an appropriation for completing the permanent connections. In these operations, the rates of discharge and velocities through the conduit were computed from the observed rise of the water surface in the reservoir during considerable periods of time, with due allowance for evaporation and leakage, as determined separately; and the corresponding losses of head by friction in the conduit were deduced from the observed heights of an open column of mercury, which was connected with the conduit at the reservoir, in comparison with the approximately measured elevations of the free water surface in the vertical 24-inch overflow stand-pipe at West Bloomfield, which is 46,338.76 ft., or 8.776 miles distant from the point of attachment of the mercurial gauge. Proper corrections for temperature were also applied to said heights of mercury, and the difference in level between the zero of

the gauge and the point of reference at the top of said stand-pipe, was subsequently determined as accurately as possible by means of the height of the column of mercury, after the inlet valve at the reservoir and the main stop-valve in the conduit south of said stand-pipe had been completely closed, as described above. The principal results obtained in 1896 and 1897 are given in the following table:

| No. of Experiment. | Date. | No. of turns opening of 8 in. by-pass valve at Reservoir. | Duration of Experiment. Hours. | Observed rise of Water in Reservoir. Feet. | Observed loss of head (h) in length of 46,339 ft. of 38-in. steel pipe. Feet. | Computed Velocity (v) in 38-in. steel pipe. Ft. per sec. | Computed Coefficient (c) in Chezy Formula: $v=c\sqrt{rs}$. |
|---|---|---|---|---|---|---|---|
| 1 | June 9-10, 1896 | 8 | 12.76 | 0 31863 | 1 562 | 0.48948 | 94 75 |
| 2 | " 10-11, " | 10 | 13 61 | 0 40274 | 2.353 | 0 61180 | 96.49 |
| 3 | " 14-15, " | 12 | 11.40 | 0 41142 | 2.804 | 0 75794 | 109.51 |
| 4 | " 14, " | 14 | 8.08 | 0.33600 | 3.755 | 0.88754 | 110.81 |
| 5 | " 13-14, " | 16 | 12 35 | 0 57792 | 5.790 | 0 96469 | 96 99 |
| 6 | " 12-13, " | 18 | 11.99 | 0 61377 | 5.818 | 1 05830 | 106 15 |
| 7 | " 12, " | 20 | 4.18 | 0.22708 | 6.093 | 1 13004 | 110 76 |
| 8 | " 12, " | 22 | 4.98 | 0 28315 | 6 559 | 1.18723 | 112 15 |
| 9 | " 11, " | 26 | 4 18 | 0.25569 | 7 688 | 1 26459 | 110 34 |
| 10 | Oct. 9, " | 26 | 8 52 | 0.49739 | 8.391 | 1 22263 | 102 12 |
| 11 | July 6-7, 1897 | 26 | 15.87 | 0.95799 | 7 553 | 1 23897 | 109 07 |
| 12 | " 7, " | 24 | 10 57 | 0 62524 | 7.159 | 1.25425 | 113.41 |
| 13 | " 9, " | 22 | 9 03 | 0 53824 | 6.571 | 1.22286 | 115.41 |
| 14 | " 9-10, " | 20 | 13 82 | 0.77871 | 5 697 | 1 15065 | 116 63 |
| 15 | " 10, " | 18 | 8.97 | 0 49900 | 5 431 | 1 10751 | 114 98 |
| 16 | " 14, " | 16 | 8.95 | 0 43968 | 4 858 | 1 02060 | 112 03 |
| 17 | " 14-15, " | 14 | 14.90 | 0 64108 | 3.793 | 0 89790 | 111 53 |
| 18 | " 15, " | 12 | 7 75 | 0 29226 | 2 850 | 0.81413 | 116.49 |
| 19 | " 15-16, " | 10 | 14.50 | 0.43561 | 1 841 | 0.63742 | 113.66 |
| 20 | " 16-17, " | 8 | 13.62 | 0.32566 | 1 179 | 0 50525 | 112 58 |

Mean value of coefficient for observations Nos. 1 to 10 inclusive, 105 01.
Mean value of coefficient for observations Nos 11 to 20 inclusive, 113.58.

It should be distinctly noted that the observations made in 1896 for the loss of head in this section of the conduit, in connection with the gaugings mentioned, were only approximate, whereas those of last year (1897) were made with the utmost care. The latter are therefore entitled to much more weight than the former. Moreover, no good reasons can be given for the incongruities in the values of the coefficient (c) for the series of experiments in 1897,

which are exhibited in the foregoing table, and the results are submitted without further comment, except that they emphasize the necessity of adopting the greatest refinement in making such measurements.

Other gaugings of the full capacity of the new conduit, with the existing temporary reservoir connections of 16-inch cast-iron pipe, were also made during the past year, the details of these operations being the same as indicated above for the old conduit. The southern part of the line, from the end of the brick conduit near the village of Hemlock Lake to Rush reservoir, consists of 91,553.61 ft. of 38-inch riveted steel pipe, and 93.60 ft. of 36-inch cast-iron pipe, valves and special pieces, thus giving a total length of 91,647.21 ft., or 17.357 miles, between points of observing loss of head; while the northern part extends from Rush reservoir to Mt. Hope reservoir, and consists of 45,393.93 ft. of 38-inch riveted steel pipe and 1,218.35 ft of 36-inch cast-iron pipe, valves and special pieces, or a total of 46,612.28 ft., or 8.828 miles, between points of observation. In this northern division, the greater part of the 36-inch cast-iron pipe is located in a continuous stretch at Rush reservoir, arrangements being made to observe the loss of head therein separately from open piezometers. It should also be noted that near the city the line makes an abrupt turn of 90 degrees, as it was intended to continue the direct line to the contemplated new distributing reservoir on Cobb's Hill.

In computing the value of the coefficient (c) in the Chezy formula $v=c\sqrt{rs}$, from the observed data, the influence of the few short sections of 36-inch cast-iron pipe and special castings in the southern division has been disregarded, and the line is treated as a continuous pipe with a uniform internal diameter of 38 inches, this being the diameter of the "inside" courses; but in the northern division, the quantity of such cast-iron pipe is large enough to warrant its separate consideration, along with the influence of the aforesaid square turn, valves and special castings, so that in this case trustworthy figures can be given for both kinds of pipe. The principal results of the various gaugings and computations which have been made on these two divisions, and which were recently revised with reference to the corrected altitude of Rush reservoir, are herewith submitted:

I. Southern Division.

| No. of Gauging. | Date. | Duration of Gauging Hours. | Observed loss of head (h), in feet in | | Computed velocity of flow (v), in feet per second, in | | Computed coefficient (c) in the Chezy formula $v=c\sqrt{rs}$ for | | Computed Discharge in gallons per day. |
|---|---|---|---|---|---|---|---|---|---|
| | | | 36-in. Cast-Iron Pipe. | 38-in. Steel Pipe. | 36-in. Cast-Iron Pipe. | 38-in. Steel Pipe. | 36-in. Cast Iron Pipe. | 38-in. Steel Pipe. | |
| 1 | Oct. 4, 1895 .... | 4.96 | None | 91 053 | None | 3.2733 | None | 116 71 | 16,661,800 |
| 2 | Dec. 23, 1895 .. | 5 02 | None | 92 899 | None | 3.2308 | None | 114 05 | 16,445,800 |
| 3 | July 23, 1897.... | 11 98 | None | 91 563 | None | 3 2482 | None | 115.50 | 16,534,400 |
| 4 | Nov. 18, 1897... | 7.43 | None | 91.398 | None | 3.1481 | None | 112.04 | 16,024,600 |

II. Northern Division.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Oct. 17, 1895.... | 5.35 | *1.234 | 72.021 | 4.2040 | 3.8756 | 129.45 | 109 35 | 19,729,700 |
| 2 | Oct 26, 1895 .. | 5.22 | †1.340 | 73 252 | 4.2386 | 3.9079 | 125 25 | 109 34 | 19,892,100 |
| 3 | Nov. 7, 1895 ... | 6 38 | 1.337 | 73 445 | 4 2340 | 3 9036 | 125 25 | 109 07 | 19,870,200 |
| 4 | July 28, 1897.... | 10 77 | 2.026 | 73 766 | 4 1281 | 3.8060 | 99 22 | 106 11 | 19,373,400 |
| 5 | Nov. 11, 1897.... | 7 92 | 4.287 | 69.521 | 4 0454 | 3 7297 | 66 84 | 107.11 | 18,985,100 |
| 6 | Nov. 19, 1897.. . | 7.08 | 4 318 | 69.609 | 4 0233 | 3.7094 | 66.24 | 106 46 | 18,881,700 |

*Obtained by mercury difference gauge.

†Determined separately; derived from computations made from the value of c(=125.25) found in succeeding Gauging No. 3.

The lengths of pipe between points of observation which were used with the computations in the foregoing table, are as follows: In the southern division, 91,640.83 ft. of 38-inch steel pipe; and in the northern division, 889.57 ft. of 36-inch cast-iron pipe and 45,393.93 ft. of 38-inch steel pipe. An examination of the last column but two of this table will also show that the friction loss in the stretch of 36-inch cast-iron pipe at Rush reservoir has increased greatly from July 28 to Nov. 11, 1897, probably in consequence of a profuse growth of organisms on the interior, similar to what was found in the old conduit at the same locality when the pipe was taken up for adaptation to the new conduit. That an error of observation was not made on the last-named date is proved by the repetition of the gauging on Nov. 19, 1897, which gave practically the same result. It is hoped that an opportunity to make a direct examination of the condition of its inner surface will be afforded during the present year. * * * * *

THE MOFFETT, HODGKINS & CLARKE COMPANY CASE.

In connection with the foregoing litigations, reference may also be made to the Moffett, Hodgkins & Clarke Company case, which has been pending in the United States Supreme Court since early in 1893, and finally came to trial last June.

This action arose from the failure of the Moffett, Hodgkins & Clarke Company to enter into contract, in January, 1893, for the construction of the new steel pipe conduit which had been duly awarded to said company by the Executive Board. Their proposal was accompanied by a bond in the penal sum of $90,000, which about 10 per cent. of the amount of the bid, conditioned that the bidder would promptly execute the contract and perform the work mentioned, if it was awarded to him. The Company, however, refused to accept the contract on the plea that a mistake had been made in their bid; and fearing that the board would attempt to recover the aforesaid large penalty, they immediately applied to the court for an injunction to restrain the city from declaring said bond forfeited.

It was alleged by the Company that a serious error had been made by their agents in writing in the accepted proposal the price of 50 cents per cubic yard for earth excavation in open trenches, instead of 70 cents as contained in a separate alternative bid for the same work if constructed along a different route for a portion of the distance; and as the total quantity of such excavation involved in the work was 184,000 cubic yards, they claimed that this error would entail upom them a loss of $36,800, if required to abide by their bid. On the other hand, a careful analysis of the bid established the fact that many of the other prices named by said Company were relatively high, and that while the proposal might be regarded as somewhat unbalanced, it was not sufficiently so as to warrant its rejection by the Board.

In the course of the trial ample evidence was offered by the city in proof that the contract could have been performed by said Company without loss, nothwithstanding their alleged error in the price for earth excavation; but the Court ignored the city's proof entirely, and singularly held that the mistakes in the bid were "clear, explicit and undisputed."

The following extracts from the decision cannot fail to be of interest to all municipal authorities:

"It would seem almost a reproach to our jurisprudence if equity be compelled to confess itself helpless in such circumstances. To grant the relief asked for does no injury to anyone. To refuse it entails upon the complainant a possible loss of $90,000; a penalty so out of proportion to its fault that its enforcement would seem repugnant to those principles of natural justice which are the foundation of all law." * * * "The law is based upon broad, general rules, applicable alike to individuals and corporations. A party dealing with a municipal corporation should not be held to the strict letter of his agreement where he would be released if dealing with an individual." * * * "If the defendants (the city) are correct in their contention, there is absolutely no redress for a bidder for public work, no matter how aggravated or palpable his blunder. The moment his proposal is opened by the Executive Board he is held as in a grasp of steel. There is no remedy, no escape. If, through an error of his clerk, he has agreed to do work worth $1,000,000 for $10, he must be held to the strict letter of his contract while equity stands by with folded hands and sees him driven into bankruptcy. The defendants' position admits of no compromise, no exception, no middle ground."

"It is argued that the mistakes were not mutual, and therefore that there is no ground of equitable cognizance. It should be remembered, however, that the complainant does not seek to reform a contract, but to be relieved from an unconscionable bid by its recission or cancellation. Equity cannot reform an agreement unless both parties were mistaken, but it can interfere to prevent the enforcement of an unjust agreement induced by the mistake of one." * * *

"It is said that the complainant has an adequate remedy at law. This objection does not appeal strongly to the Court in a case where all the parties are on the record, where all the facts bearing upon the transaction have been collected with great diligence and expense, and where the questions in dispute have been fully and ably debated. In such circumstances the Court should not, unless clearly compelled to do so, adopt a course which will render nugatory all this labor and expense. Believing that the complainant is entitled to relief, the duty of granting it should not be devolved upon another tribunal in order that a doubtful theory may be vindicated." * * *

"The complainant is entitled to a decree rescinding its proposals, and enjoining the defendants as prayed for in the bill."

While it may not be in good taste for a layman to criticise the findings of a high tribunal, it is nevertheless fair to the officers of the city to say that the proof of their side of the case was so strong as to make it impossible for them to admit the full justice of this decision. By the failure of the Company to execute the contract and the award of the work to the next bidder, the city sustained a loss very much larger than the amount of the bond, which circumstance seems to have been entirely overlooked by the judge when he stated that the granting of the relief asked for by the Company did no injury to anyone. The fact is that a large burden of additional expense was thereby placed upon the taxpayers of this community, and it is also a fact that many other courts have held that a mistake of the kind which is alleged to have been made cannot free a bidder from responsibility therefor.

If this decision is a sound one, then the practice of advertising for proposals for the performance of public work becomes a simple farce, and all charter provisions which require the executive officers of municipalities to advertise for proposals can only have the effect of imposing unnecessary expense upon the taxpayers, and of inviting fraudulent collusion between bidders after the proposals have been opened and read. It will then be extremely easy for a high bidder to induce the low ones to allege that they had made a mistake in their figures, and as the bonds which they may have given as evidence of good faith on their part can readily be declared void by a court, a municipality can be mulcted to untold extent by being compelled to have its public work performed at excessive prices. From the standpoint of sound public morality, it does not seem possible that the broad road which has thus been opened to dishonorable practice by contractors can be maintained, and an appeal from this decision has accordingly been taken.

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# ABSTRACT FROM THE REPORT OF THE DEPARTMENT OF PUBLIC WORKS, ST. JOHN, N. B.

BY WM. MURDOCK, ENGINEER AND SUPERINTENDENT.

* * * * * * * * * *

The Common Council having passed an order on the 17th day of June directing that the mains leading from Little River Reservoir to the city be cleaned, preparations were at once begun to carry out that order.

As there were no hatch boxes laid in the original construction of the lines, drawings and specifications had to be prepared, and on August 6th a contract was awarded to Mr. James Fleming to cast eight hatch boxes for 24-inch pipe (afterwards increased to nine) and four hatch boxes for 12-inch pipe as well as all the requisite sleeves at the rate of two cents per pound. Excavating was commenced at the reservoir for placing the boxes on leading mains Nos. 1 and 2 on September 11th; the first hatch box was delivered on October 1st, and the main was cut and hatch box inserted October 6th.

Advantage was taken of this opportunity to remove the old receiving chamber which connected mains 1 and 2, and of extending No. 1 main up to the receiving chamber placed in the year 1873, when No. 3 main was laid. At that time this chamber could not be removed without stopping the city's supply; so it was left in. This extension was made and the 12-inch hatch box placed October 7th.

Cleaning water mains having never been attempted here before and the business being new, particular pains were taken to prevent any mishap. In designing the cleaner or mechanical scraper special precautions were taken to avoid the misfortune of having it lodge in the pipe with such consequent vexatious searchings, and cuttings of pipe as have often occurred elsewhere. The desiderata laid down were:

(*a*) That the apparatus be as light as possible, so as to be easily projected up ascending gradients by the pressure of the water and

to offer generally as little resistance as possible, whether through inertia or otherwise :

(*b*) That as it is more desirable to take light cuts and make frequent runs than attempt to remove all the dirt at once and have the scraper stick, therefore the pistons should be so loose as to permit a free escape of water to carry off the loosened dirt in advance of the cleaner, and that the arms be not so rigid as to hold it up against any hard and abrupt obstructions encountered.

With these maxims in view, the machine was made as shewn in the accompanying illustration,* the pistons being of birch set in layers, each layer being one inch in thickness and placed crosswise of the other to prevent warping, and increase the strength of the piston. Leathers were secured to the piston by means of an iron ring bolted against them, the bolts being run through the piston.

The spindle connecting the two pistons is of 3-inch wrought iron pipe with a cast iron flange screwed on each end and pinned over with a hammer to prevent the screw backing out. These flanges are each bolted through the pistons to another flange on the opposite side.

Projecting beyond the forward piston is an iron rod fitted with two sets of radial arms sloping back as shewn in the cut. There are four arms in each set, made of No. 10 (B. W. G.) spring steel 2 inches wide and each fitted with a forged steel scraper on the end, of the form shewn in the accompanying illustration. The long sloping fish-tail form of this scraper enables it to glide safely over every obstruction.

In making the first runs only one set of scrapers was attached, but in the latter the whole eight were in use. This precaution was taken lest a large amount of dirt should be loosened at once and the cleaner become buried and stop.

On October 12th, No. 2 hatch box was placed on No. 2 main at Hickey Road, a distance of 6,000 feet from the reservoir and at 1 p. m. the same day the work of cleaning began.

The head of water upon the upper hatch box was 20 feet and on the lower 27 feet. The first run took four hours, for the reason that a cord sufficiently long to reach the whole length had been placed on a revolving drum 10 feet in circumference and furnished

*The illustration is omitted for want of time to reproduce it.—EDITORS.

with an indicator to register the revolutions. The end of this string was attached to the drum and a record kept of its location as it sped along. But when the first flushing branch was reached the twine drifted out here and down the brook while the drum kept on revolving and the indicator registering until the whole string was paid out. Meanwhile the cleaner had become securely moored near the flushing branch and could not be liberated until the stopcock was dug to and uncovered. On the twine being cut and pulled out and the stopcock lid restored, water was let on again and the cleaner finished its journey, a distance of 2,200 feet, in about five minutes.

This first run was sufficient to shew that twine was dangerous; and we also learned that it was entirely unnecessary, for the grating sound of the cleaner as it passed through the pipe was heard quite distinctly by the two watchers, under their feet as they followed the sound along the line.

Two more runs were given that same afternoon, the time occupied to go the distance being about twenty minutes.

The water was inky black for some time as it flowed from the flushing pipe and it was allowed to run for two hours after the cleaner had been removed, this time having been required for the water to clarify.

The next section was taken on Saturday, October 23d. It extended about 6,600 feet cityward, but in order to give the first section another scraping it was concluded to insert the cleaner at the dam and run it through the entire 2.4 miles.

A misfortune was met this time in the following manner: The leathers having worn out during the first cleaning, they were renewed with a harder and stiffer quality than before, but they repeatedly caught in a new joint made while inserting the hatch box. Each time the lid was removed to ascertain why the cleaner did not start it was found firmly fixed by this imperfect butt of the two pipe ends. After twice extricating it and again finding it caught in the same way, a jack-screw was applied to push it past this obstruction, the lid was again put on and the water let in at 4.05 p. m. This time it started. At each of the five flushing stations the gate was left open fully ten minutes after the cleaner had passed and then closed. As soon as the gate was closed the cleaner again proceeded and the scraper *with only one piston* reached the end of its run at 5.25 p. m., having been one hour and twenty

minutes going 2.4 miles, but when the fifty minutes of total stoppages are reckoned, the machine was found to have been in motion thirty minutes.

As stated, only the forward part of the cleaner arrived, and search had to be made for the remainder. Nothing was done on the following day, which was Sunday, the castaway piston which was lying obliquely somewhere in the pipe having but partially obstructed the flow, and the water was left on till the Monday night following.

A receiving chamber unites Nos. 2 and 3 mains near No. 3 hatch box and they are controlled by stop cocks on each side of the receiver. It was, therefore, an easy matter to reverse the current of water in No. 3 by closing the stop cock at the dam, and opening that at the receiver as well as the flushing branches. This was done, and men were distributed along the line to listen for a rumbling noise, which at length was heard about one-quarter mile of hatch box No. 3 from which the cleaner had been extracted. The sound was followed along the line toward the reservoir until hatch box No. 2 was reached when the derelict was taken out, after having travelled nearly a mile and crossed a valley about 90 feet in depth. It was found that the pressure of the jack-screw in forcing the cleaner past the uneven joint had cracked one of the flanges, with the result that after having travelled 2¼ miles the cleaner fell apart. The forward part comprising a piston and the scraper, pushed on, but the spindle attached to the rear piston fell to the bottom of the pipe, ploughed up some dirt and finally imbedded and jammed. The reverse current striking the piston as it did, drove it back, with the spindle trailing behind.

The apparatus was repaired and three more runs made through this double section of 12,600 feet, on October 27th, without any further mishap, the time taken for each run, including a ten minutes stoppage at each of the five flushing stations having been one hour and forty minutes to two hours and thirty minutes. The cold weather being on when the next casting arrived, cleaning operations were suspended for the season, to be resumed next spring.

On testing the efficiency of the cleaned main by shutting off No. 3 from the reservoir to the receiving chamber where both unite, and bringing the supplies through Nos. 1 and 2, it was found that the pressure in the city was as good as when No. 2 was

shut and the whole supply coming through Nos. 1 and 3, thereby showing that the capacity of No. 2 had improved to such an extent that when with No. 1 it had formerly delivered to a height of 80 feet only, when unassisted by No. 3, and left 200 acres of the city containing 8,500 inhabitants without water, now the whole city could be supplied without the help of No. 3 and the water rise to a height of 130 feet above high water. The general improvement in pressure with all the mains on was found to be about four feet.

Nearly two miles of this line remain yet to be cleaned, after which the other two pipes will be taken as soon as the coming season permits. * * * * *

## ABSTRACT FROM THE REPORT OF THE WATER COMMISSIONERS, TROY, N. Y.

BY WILLIAM G. RAYMOND, ENGINEER.

* * * * * * * * * *

### DAMAGES TO MILL POWERS.

It has been said that every dweller along a stream has a common law right to have that stream continue to flow as it has ever been accustomed to do. This is true. But the law also provides that a municipality may take a portion, or all, of the water of the stream for public use, provided it pays the dwellers along the stream who may be affected by the diversion of the water, suitable sums of money as damages.

The determination of these sums is usually entrusted to a commission acting under the authority of a court. The awards made by such commission may be appealed from to the court.

It will readily be understood that it is absolutely impossible to predict what any commission will judge to be the damage sustained by each of the individuals affected by the diversion of the flow of the stream. It is, however, possible to make an estimate of what will be a fair and reasonable allowance. There are many considerations that enter into such an estimate, and it is not a simple matter to arrive at the conclusion.

In the cases of the Quackenkill, Poestenkill, or Tomhannock streams, it is safe to predict that the damage sustained by the farmers along the streams, who have no mill powers, will be nominal, since not all the water will be diverted, and enough will be left for the watering of stock, and similar farm uses. Moreover, some of these dwellers will be distinctly benefited by a lessening of the spring flood water.

I have on former occasions stated in an informal way, that the methods of arriving at the damages to be awarded the owners of mill privileges for the diversion of a part or all of the flow on which they depend for power have changed in recent years. This statement has been questioned. I wish to reaffirm what I have said on this subject. So far as I know the law has not changed, but the method of determining the measure of damage has changed.

The following method has prevailed in the past:

A city proposes to build works that will enable it to draw ten millions of gallons of water daily from a stream. Below the point of diversion is a mill power with twenty feet of fall or head. The miller claims that ten millions of gallons daily over twenty feet fall means thirty-five horse power, good the whole twenty-four hours; or by storage in his mill pond it is good for eighty-four horse power for ten hours daily. At his particular location, out in the country, coal is high, and he estimates that it will cost him, including interest, sinking fund, repairs, fuel, oil, attendance, etc., $60.00 per horse power per year for ten hours daily. Eighty-four horse power would then cost $5,040 per annum. This sum capitalized at six per cent. gives $84,000 as the damage to him for the diversion of the water. He may not be quite so grasping as this, and may admit that his plant is built for only fifty horse power, and that this is all he can use, and that this is what will be destroyed, and hence he asks payment on the basis of fifty horse power, Damages have been awarded on just such estimates as these. It will be observed that no account has been taken of any one of the following points, one or all of which may be pertinent to the particular mill in question:

I. The same reason that makes coal high makes the cost of hauling raw material and finished product high. The miller could operate to better advantage in some other place.

II. His business does not demand eighty-four horse power nor fifty horse power. The unutilized power is certainly not of the same value as that that is used.

III. He needs steam for heating, and possibly also for manufacturing purposes, necessitating the maintenance of a boiler plant. Exhaust steam from an engine will do as well for these purposes. thus reducing the cost of steam power,

IV. The stream is irregular in flow so that to keep up regular power he has been already obliged to install a steam plant. Interest on first cost, a large portion of the repairs and the cost of running for the average time now run should not be chargeable to the city.

V. The stream is irregular, and the mill pond is not large enough to permit the use of the full supply, and perhaps not to give fifty horse power at all times. The power thus wasted should not be charged to the city.

VI. The flow of the stream is irregular, and throughout a con-

siderable portion of the year it is less than ten millions of gallons daily. Only the actual flow stopped should be considered for this period.

VII. The flow of the stream is irregular, and during a considerable portion of the year the flow is so great that the power that it is feasible to develop at the mill will not be in the least lessened by the water taken by the city. For this period no damage should be claimed.

VIII. It costs something, singular as it may seem, to develop water power. Only the difference between the cost of operating by water and steam should be considered. It is true that some of this cost of water power, such as the interest on cost of dams and reservoirs that must go on even though steam be substituted for water, can not be offset in this way.

IX. The average run of water wheels do not develop more than two-thirds of the theoretical power of the water, and the very best do not average more than three-fourths throughout the year. It is clear that no more than this should be charged as net horse power.

X. Last but not least, the business that the miller carries on yields him a net revenue of not to exceed $1,000 annually, and so far as it appears he is getting all out of it that can be gotten. Is he to be paid five times the value of the business for destroying a part or even all of it?

In the past many or all of these considerations, favorable to the city, were omitted in the estimation of the measure of damage. Today they are considered, together with some other items that are favorable to the mill owner. Different considerations arise for different powers. The single item of transportation has come to mean much more than it once did. Moreover, the laws of trade are such that a manufacturer can not make up a great quantity of goods when power is plenty and hold them till called for. He must run when he gets the orders, and this may be when there is no water to run with. These considerations have done much to lessen the value of power on irregular, small streams. This is evidenced by the number of mills on such streams that have been abandoned as worthless. On the Tomhannock there were formerly a number of mills, flax mills, paper mills, cotton mills, powder keg factory, etc. Now there is practically nothing left of all these; two or three country grist and saw mills being all.

Coming now to a consideration of the streams near Troy we may estimate somewhat as follows;

The assessed value of the less important country privileges that will be affected is about $12,500, The country assessments are very uncertain as to their relation to true value. Assuming that they represent half value, it would require $25,000 to purchase them all.

Exclusive of these powers treated in this way, there are other more important powers in the country and city having an aggregate head available of about 280 feet. Each million of gallons daily over this head, assuming it to be well developed is equivalent to about 49.1 horse power throughout the twenty-four hours. Many of the plants run but ten hours, and others run twenty-four hours when there is water to run. With a single exception all of the more important powers are already supplied with steam power. Very few water powers are maintained for less than $8.00 to $12.00 per annum per horse power. We will assume $10.00 in these cases.

Twenty-four hour power can be furnished by steam to most of these mills for not to exceed $98.00 per annum per horse power. Add the cost of the interest on the steam plant, the cost of operating a portion of the year, and a part of the sinking fund, etc., to the cost of maintaining the water power, and the difference between water and steam power on these streams will not be more than $38.00 per annum per net horse power. Some of the mills use water in considerable quantities for manufacturing purposes and due allowance should be made for this.

Ten millions of gallons over a total head of 280 feet will represent about 491 twenty-four hour horse power. With an efficiency of 75 per cent. for the wheels, a difference of cost by steam or water of $38.00 per net horse power, and interest at six per cent., there results a gross valuation of the damage arising to these mills—assuming the diversion of the water to affect them continually—of $233,225.

There are from four to six months during which the flow is so great that, according to some of the mill people themselves, our diversion of the water of the upper portion of the watershed will not affect them in the least. There are several months of the year during which the flow of the stream is not ten millions of gallons

daily, when indeed, including the flow of the upper storage ponds, it will not exceed four millions daily. Assuming these facts the damage reduces to less than $100,000 after adding the cost of purchasing the country mills. To take eighteen millions daily will on this basis cost less than $160,000. It will be many years before this amount of water is required, and hence the present value of the damage should be less than these sums. It should be the amount of the present damage added to a sum which placed at interest now will equal the estimated future damage by the time the future damage will be sustained.

It is thus seen that the estimate of $125,000 made some years ago is not so far out of the way. The damages actually awarded may of course exceed this amount. It is only an estimate, based on the powers as a whole. But it should be said that a number of these powers heretofore considered important have been idle for a number of years.

It is well to form some idea of the probable cost of such a work as this is before undertaking it, but the best that can be done, unless you desire to settle with these owners on their own terms, is to make an estimate based on the facts known, and on experience elsewhere when details for the case in hand are not available. It is therefore proper to note that in a number of recent cases the awards of the commissions have been somewhat singularly about ten per cent of the claims of the owners. It is of course well to consider these claims of owners, but what sane man would use this as a basis of settlement? And what owner expects that it will be so used? It is worthy of note in this connection, that in the case of Syracuse, the awards were almost exactly one-tenth of the claims. It is but right to say that these cases are not all finally settled.

Inquiries sent by me to the various owners of privileges along the Poestenkill and Quackenkill have been answered sufficiently to enable me to estimate the probable amount of claims at $400,000.

It is interesting to note in this connection that the entire assessed valuation of all the mill privileges on both streams, from the mouth of the Poestenkill to the summit of the mountains, including the buildings and real estate appertaining, and including in this more than one hundred acres of land over and above the acreage in the storage ponds in the country, is less than $290,000.

* * * * * * * * * *

# NEW ENGLAND WATER WORKS ASSOCIATION

# MEMBERSHIP ROLL.

## SEPTEMBER 1, 1898.

NOTE.—The Secretary requests to be advised of existing errors or change of address from that which appears in the following list.

### ACTIVE MEMBERS—RESIDENT AND NON-RESIDENT.

Abbot, Everett L.
Box 2281, Boston, Mass.

Adams, John D.
Superintendent, Provincetown, Mass.

Allen, Charles A.
Civil Engineer, 44 Front Street, Rooms 109 and 110, Worcester, Mass.

Allen, Charles F.
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